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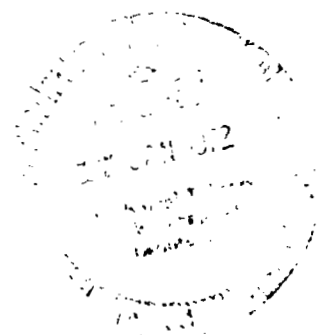
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**AN INVENTORY OF
AERONAUTICAL GROUND
RESEARCH FACILITIES**

Volume IV — Engineering Flight Simulation Facilities

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Advanced Concepts and Missions Division
Moffett Field, Calif.*





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16. Abstract This Volume of the Aeronautical Ground Research Facilities Inventory presents the general purpose capabilities of government and industry in the area of real time engineering flight simulation. While these facilities include several Space System Simulators, elements of the respective facilities are considered to be of general purpose application and therefore are consistent with the objectives of this report. Information contained herein covers computer equipment, visual systems, crew stations and motion systems, along with brief statements of facility capabilities. Facility construction and typical operational costs are also included where available. Collectively, these facilities provide for economical and safe solutions to vehicle design, performance, control and flying qualities problems of manned and unmanned flight systems.					
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PREFACE

McDonnell Aircraft Company has conducted an inventory of Aeronautical Ground Research Facilities under contract number NAS 2-5458 (Modification 1) for NASA's Advanced Concepts and Missions Division, Office of Advanced Research and Technology (OART), located at Ames Research Center, Moffett Field, California. The inventory is intended to provide sufficient documented facility information to be used by government and industry engineers and scientific personnel for planning test programs relative to advanced aeronautical systems. The inventory is arranged by major facility category in four volumes for convenience.

Volume I - Wind Tunnels
Volume II - Airbreathing Engine Test Facilities
Volume III - Structural Environmental Facilities
Volume IV - Engineering Flight Simulation Facilities

The primary content of each volume is a compilation of facility data pages which provide information descriptive of the general arrangement, performance, testing capability, and, where available, acquisition and operating costs of each facility inventoried. Also, sufficient additional source references are provided for those requiring more detailed information. An index of facilities is provided which is arranged alphabetically by reporting installation. Summary tables in each volume list facilities by type and alphabetically by reporting installation, along with brief data descriptive of the facility.

This inventory was accomplished in five basic steps which included: (1) a literature search to identify candidate facilities, (2) formulation and distribution of appropriate questionnaires to facility operators, (3) preparation of preliminary facility data pages (based on completed questionnaires), (4) technical review of facility data pages, and (5) final drafting of the report.

The facilities included in this inventory do not necessarily represent the total ground research capability of each reporting installation, but rather its major capabilities.

VOLUME IV - ABSTRACT

ENGINEERING FLIGHT SIMULATION FACILITIES

This volume of the Aeronautical Ground Research Facilities Inventory presents the general purpose capabilities of government and industry in the area of real time engineering flight simulation. While these facilities include several Space System Simulators, elements of the respective facilities are considered to be of general purpose application and therefore are consistent with the objectives of this report. Information contained herein covers computer equipment, visual systems, crew stations and motion systems, along with brief statements of facility capabilities. Facility construction and typical operational costs are also included where available. Collectively, these facilities provide for economical and safe solutions to vehicle design, performance, control and flying qualities problems of manned and unmanned flight systems.

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B. SUMMARY TABLES

A. FLIGHT SIMULATORS (Government Owned)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
AFASD Wright-Patterson Air Force Base, Ohio Crew Station Simulation Facility FB-111A Simulator	Engineering tool for weapon system development and implementation	Motion Platform 5-DOF	Closed circuit TV of two moving model systems displayed through collimating lenses to the pilot	SIGMA 5 and two Singer/Link Mark I Digital Computers	2
AFASD Wright-Patterson Air Force Base, Ohio Crew Station Simulation Facility C-135B Simulator	Engineering tool for weapon system development and implementation	Motion Platform 3-DOF	Closed circuit TV of two moving model systems displayed through collimating lenses to the pilot	SIGMA 5 and two Singer/Link Mark I Digital Computers	2
AFASD Wright-Patterson Air Force Base, Ohio Crew Station Simulation Facility F-4D Simulator	Engineering tool for weapon system development and implementation	Motion Platform 3-DOF	Closed circuit TV of two moving model systems displayed through collimating lenses to the pilot	SIGMA 5 and two Singer/Link Mark I Digital Computers	2
AFAMRL Wright-Patterson Air Force Base, Ohio Air Force Dynamic Environment Simulator Dynamic Environment Simulator	Simulation of stresses encoun- tered by aircrew members during flight and escape maneuvers	Double Gimballed Human Centrifuge Can produce a 20g field	Unknown	PDP-1 Digital Computer	6
AFHRL Brooks AFB, Texas Simulation and Training Media Development System	Exploratory development of simulation tech- niques, instruc- tional media and training innovations	Motion Base 2-DOF	Modified SMK-23 Visual Simulator Training Attachment. View represents an airfield and sur- rounding terrain features	XDS SIGMA 5 Digital Computer with 16K- 32-Bit Memory	8
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators Five-Degree-of-Freedom Motion Generator	Spacecraft launch and re-entry evaluations along with evaluations of aircraft han- dling qualities and control systems	Motion Base Swing Arm Type 5-DOF	TV monitors	General Purpose Analog-Digital Computer System	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Flight Simulator for Advanced Aircraft	Studies of stability, load- ing and related transport-type aircraft handling, control systems and crew tasks	Motion Platform 6-DOF	Color televised model projected on front screen and viewed through collimated lens	Hybrid Digital- Analog Computer System (EAI 8400)	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Height- Control Test Apparatus	Research into aircraft requir- ing sustained vertical acceler- ation	Motion Base 1-DOF (Vertical Translation)	Closed circuit TV monitor	Analog	80

A. FLIGHT SIMULATORS (Government Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Moving- Cab Transport Simulator	Evaluation of aircraft handling qualities and control systems during approach, landing, and taxiing	Motion Base 3-DOF (Vertical Translation and Pitch and Roll Rotation)	Closed circuit color TV monitor of landing scene	Analog	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Six- Degree-of-Freedom Motion Simulator	Research of V/STOL aircraft approach and landing flying qualities and control system characteristics	Motion Base 6-DOF	Closed circuit TV display of approach and landing	General Purpose Digital/Analog Computer Systems	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Vertical Acceleration and Roll Device	Research on air- craft and space- craft, and medical investi- gations requiring normal and roll accelerations	Motion Base 2-DOF (Vertical Translation and Roll Rotation)	Closed circuit TV display of landing approach	Analog	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Fixed-Base Transport Simulator	Evaluation of aircraft crew tasks	Fixed Base	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Midcourse Navigation Simulator	Assessment of space navigation instruments and procedures	Unknown	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Flight and Guidance Centrifuge	Simulation of spacecraft missions	Unknown	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Man- Carrying Rotation Device	Physiological studies	Unknown	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Biosatellite Centrifuge	Determination of g tolerance of biological sub- jects	Unknown	Unknown	Unknown	80

A. FLIGHT SIMULATORS (Government Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Environmental Chamber	Studies involving altitude, atmos- phere composi- tion, or temperature capability	Unknown	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Portable Chamber	Studies involving altitude or atmospheric compositions with centrifugation	Unknown	Unknown	Unknown	80
NASA-ARC Moffett Field, Calif. NASA Ames Flight Simulators. Human Environmental Test Facility	Studies involving altitudes, atmospheric composition, and temperature or temperature cycling	Unknown	Unknown	Unknown	80
NASA-FRC Edwards AFB, Calif. NASA FRC Simulation Laboratory	Primary purpose is manned real- time flight simulation	Unknown (Facility has six Crew Stations)	Flying spot scanner and contact analog visual scene generators	Two digital (XDS 9300 and XDS 930) and four Analog (EAI 231R-V, EAI 231R, and two ADI AD-4) computers with two separate XDS Interface Systems	88
NASA-LRC Hampton, Virginia NASA Langley Attitude Control Simulation Facility. Solar Radiation Simulator	Evaluation of spacecraft attitude stabili- zation and con- trol systems	Unknown	Unknown	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	90
NASA-LRC Hampton, Virginia NASA Langley Attitude Control Simulation Facility. Planet Radiation Simulator	Evaluation of spacecraft attitude stabili- zation and con- trol systems	Unknown	Unknown	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	90

A. FLIGHT SIMULATORS (Government Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
NASA-LRC Hampton, Virginia NASA Langley Attitude Control Simulation Facility. Three Star Simulators	Evacuation of spacecraft attitude stabili- zation and con- trol systems	Unknown	Unknown	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	90
NASA-LRC Hampton, Virginia NASA Langley Flight Control Research Facility. Fixed Base Cockpits	Basic IFR aero- nautic research in handling qualities and instrument dis- play development	Fixed Base	Unknown	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	92
NASA-LRC Hampton, Virginia NASA Langley Flight Control Research Facility. Differen- tial Maneuvering Simulator	Basic research and evaluation of manned differen- tial maneuvering	Fixed Base (Two Crew Stations in 40 ft-dia Spherical Pro- jection Screens)	TV camera pickup of sky, Earth, and target models, and projected on 40 ft. dia. spherical pro- jection screen	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	92
NASA-LRC Hampton, Virginia NASA Langley Flight Control Research Facility. Six-Degree-of-Freedom Motion Base	Basic studies of motion - visual effects	Motion Base 6-DOF (Installation in Mid-1971)	CRT-virtual image display	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	92
NASA-LRC Hampton, Virginia NASA Langley Flight Control Research Facility. Virtual-Image Display Simulator	Provides a 90 deg refractive virtual-image presentation for general applica- tion to space and aeronautical studies	Unknown	Terrain-scene and target-vehicle image from high- intensity kinescope projectors	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Com- puters, three Full- Expanded EAI 231R, and two GPS 10,000 Repetitive-Opera- tion Computers)	92

A. FLIGHT SIMULATORS (Government Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
NASA-LRC Hampton, Virginia NASA Langley CMG Research Laboratory. Control Moment Gyro	Real time evaluation of full-scale control moment gyro in a simulated dynamic environment	Three-Axis Servo Table	Unknown	LRC Central Data Reduction Center and tie-ins. (CDC 6600 Digital and EAI 680 Analog)	96
NASA-LRC Hampton, Virginia NASA Langley Simulation Research Laboratory. Transport Aircraft Simulator	Transport aircraft research studies and blown-flap STOL research	Fixed Base	CRT-virtual image window display tied to terrain scene generator	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Computers, three Full-Expanded EAI 231-R, and two GPS 10,000 Repetitive-Operation Computers)	100
NASA-LRC Hampton, Virginia NASA Langley Simulation Research Laboratory. Tactical Effectiveness Simulator	Tactical effectiveness studies (developed as forerunner to the differential maneuvering simulator)	Fixed Base	Aircraft target, sky-Earth-horizon, and limited-field terrain projected on a 20 ft dia. projection screen	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Computers, three Full-Expanded EAI 231-R, and two GPS 10,000 Repetitive-Operation Computers)	100
NASA-LRC Hampton, Virginia NASA Langley Simulation Research Laboratory. Foot Controlled Maneuvering Unit	Space locomotion studies involving foot-controlled devices	Fixed Base	Aircraft target, sky-Earth-horizon, and limited-field terrain projected on a 20 ft dia. projection screen	LRC Central Data Reduction Center and tie-ins. (Four Control Data 6000 Series Computers, three Full-Expanded EAI 231-R, and two GPS 10,000 Repetitive-Operation Computers)	100
NASA-LRC Hampton, Virginia NASA Langley Rendezvous Docking Simulator	Orbital docking and aircraft handling evaluations, and basic motion studies research	Motion Base 6-DOF	Closed circuit TV	LRC Central Data Reduction Center and tie-ins. (CI 5000, CI 150, and EAI 231-R Computer Systems)	104

A. FLIGHT SIMULATORS (Government Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer System	Page
NASA-MSFC Marshall Space Flight Center, Alabama Computation Laboratory Physical Simulation Facility. Lunar Roving Vehicle Simulator	Evaluation of candidate con- troller param- eters, crew station layout, crew procedures, control console layout and func- tions, and of navigation systems.	Motion Base 6-DOF	Out-the-window view of a closed circuit televised image of a typical rough lunar terrain model	Three Hybrid Computer Complexes	106
NADC Warminster, Pa. Computer Simulation Facility Aircraft and Air Weapon System Simula- tion	Man-machine aircraft and weapon systems studies	Fixed Base Cockpit	DEC 338 Programmed Buffered Display System	Four EAI 8812 Analog Computers, CDC 6600 and EAI 640 Digital Computers	114
NADC Warminster, Pa. Computer Simulation Facility Air-to-Air Combat Simulation	Visual air-to-air combat studies	Fixed Base Dual Cockpits	Unknown	Four EAI 8812 Analog Computers, CDC 6600 and EAI 640 Digital Computers	114

B. FLIGHT SIMULATORS (Industry Owned)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
Bell Aerospace Co. Buffalo, New York Bell Visual Simulation Facility	Simulates a wide variety of space, lunar, and earth environments	Both Fixed Base and Motion Base	Closed circuit TV of terrain and vehicle models transmitted to a back projection screen in front of the pilot	Hybrid Digital-Analog Computer System. (IBM 7090, TR-48, three PACE 231-R and two AD-4's)	10
Boeing Company Seattle, Washington Boeing Aerospace Visual Flight Simulator	Research tool used for development and evaluation of aircraft design changes, cockpit suitability, and pilot performance functions	Several Fixed Base Crew Stations	Closed circuit TV visual display of several models, globes, and aero-photo mosaics	XDS 930 Digital Computer in conjunction with a Varian 622i Digital Computer and a Sanders ADDS 900 Graphic Display System	14
Boeing Company Seattle, Washington Boeing Kent Simulator Center. Multistress Chamber Cockpit	Studies of human performance in environment of vibration, heat, pressure, noise, illumination and atmosphere	Fixed Base	Unknown	IBM 360/65 System and a General Purpose XDS 9300 System. Also a variety of Analog Computers.	18
Boeing Company Seattle, Washington Boeing Kent Simulation Center. Air Traffic Control Center	Development and evaluation of traffic systems and command control systems	Fixed Base	Unknown	IBM 360/65 System and a General Purpose XDS 9300 System. Also a variety of Analog Computers.	18
Boeing Company Seattle, Washington Boeing Kent Simulation Center. Space Shuttle Vehicle Cockpit	Development and evaluation of spacecraft, boosters, and command control systems	Fixed Base	Unknown	IBM 360/65 System and a General Purpose XDS 9300 System. Also a variety of Analog Computers.	18
Boeing Company Philadelphia, Pa. Boeing Flight Simulation Facility. Flight Simulator	For performing unmanned and piloted real-time flight simulation studies of aircraft, control system, and instrumentation concepts and configurations	Small Motion Base 6-DOF	Computer-generated out-of-the window collimated visual display	Hybrid Computer System (IBM 360/44 and four AD-4 Systems)	20
Fairchild Hiller Corp. Farmingdale, New York Fairchild Hiller Flight Simulation Laboratory	Represents a realistic in-flight environment for the pilot	Fixed Base	Large screen scope for out-of-the-window visual display	Analog	24

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
General Dynamics Corp. Fort Worth, Texas General Dynamics Electronic Warfare Cockpit Simulation Laboratory. Electronic Warfare Cockpit Simulator	Evaluation tool for air-to-air weapon delivery, penetration aids development, handling quali- ties, system design param- eters, and man- euver develop- ment	Fixed Base	Black-and-white TV system used to project target air- craft image on a forward field-of- view screen	Hybrid Computer System (CDC 6600 Digital and two fully expanded EAI 8800 Analog Computers)	26
General Dynamics Corp. Fort Worth, Texas General Dynamics Electronic Warfare Cockpit Simulation Laboratory. General Purpose Cockpit Simulator	Evaluation of attack systems and penetration aids systems	Fixed Base	Black and white TV system used to project target air- craft image on a forward field-of- view screen	Hybrid Computer System (EAI 640 Digital and EAI 231-R Analog Computers)	26
General Dynamics Corp. Forth Worth, Texas General Dynamics Electronic Warfare Cockpit Simulation Laboratory. F-111 Cockpit Simulator	To evaluate air- craft handling qualities, estab- lish control sys- tem design param- eters and to eval- uate dynamic wing and tail loads during maneuvers	Fixed Base	Unknown	EAI 8812/CDC 6600 Hybrid Computer	26
General Dynamics Corp. San Diego, Calif. General Dynamics Simulation Laboratory. Integrated Manned Systems Simulator	Design and research tool for manned air- craft and aero- space systems	Fixed Base	Visual out-of-the- window set of television studios	Hybrid Computer System (XDS 930 and CDC 6400 Digital and three CI 5000 Analog)	30
Grumman Aerospace Corp Bethpage, New York Grumman Systems Simulation Laboratory. Full Mission Engineering Simulator (Lunar Module)	Verification of actual lunar module flight article capa- bilities, including descent from lunar orbit and ascent to rendezvous and docking	Fixed Base	Closed circuit TV images reflected by beam splitters into 5 ft dia. parabolic mirrors and then into the IM cabin windows	IBM 7094-II and IBM 1800 Digital and three REAC 500 Analog Systems	34
Grumman Aerospace Corp Bethpage, New York Grumman Systems Simulation Laboratory. Three-Degree-of- Freedom Motion Simulator	Investigation of pitch, roll, and heave motions	Motion Base 3-DOF	Unknown	IBM 7094-II and IBM 1800 Digital and three REAC 500 Analog Systems	34

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
Grumman Aerospace Corp Bethpage, New York Grumman Systems Simulation Laboratory. Two-Degree-of-Freedom Simulator (Lunar Mobile Base Vehicle)	Simulation of a roving lunar mobile vehicle	Motion Base 2-DOF	Projection of simulated lunar terrain on rear projection screen in front of the crew station	IBM 7094-II and IBM 1800 Digital and three REAC 500 Analog Systems	34
Grumman Aerospace Corp Bethpage, New York Grumman Systems Simulation Laboratory. One-Sixth Gravity Simulator	Evaluation of different metalastic wheel configurations for lunar roving vehicles	Unknown	Unknown	IBM 7094-II and IBM 1800 Digital and three REAC 500 Analog Systems	34
Hughes Aircraft Co. Culver City, Calif. Hughes Man-Machine Simulation System Laboratory. General Purpose Cockpit Controls and Displays Simulator	Demonstration and evaluation of air-to-ground weapon delivery from target acquisition to launch	Fixed Base	Heads-up display television monitor with a refractive optic collimating system	General-Purpose Hybrid Computer System. (XDS 9300 Digital, two AD-4 and one EAI 231-R Analog Computers)	40
Hughes Aircraft Co. Culver City, Calif. Hughes Man-Machine Simulation System. F-14 Mission Control Officer's Mission Simulator	Evaluation of operator per- formance in acquiring tar- gets under many different simulated condi- tions	Fixed Base	F-14 MCO crew station cockpit displays	General-Purpose Hybrid Computer System. (XDS 9300 Digital, two AD-4 and one EAI 231-R Analog Computers)	40
Hughes Aircraft Co. Culver City, Calif. Hughes Man-Machine Simulation System. Advanced Avionics Simulator	To demonstrate the feasibility of advanced tactical air- craft systems	Fixed Base	Radar, tactical electronic warfare, and head-up displays located in the cockpit	General-Purpose Hybrid Computer System. (XDS 9300 Digital, two AD-4 and one EAI 231-R Analog Computers)	40
Lockheed Aircraft Corp Sunnydale, Calif. Lockheed Crew Systems Simulation Laboratory. Visual Simulator	Evaluation of manual control of space, undersea, and surface vehicles	Fixed Base	Televised scene elements are presented at a 10 x 13 inch window through virtual imaging optics	SEL 810A and Varian 620i with 8K Core Each	44
Lockheed Aircraft Corp Sunnydale, Calif. Lockheed Crew Systems Simulation Laboratory. Solar Illumination Simulator	Creation of space photometric conditions for evaluating visi- bility in manned space-vehicle environments	Fixed Base	Unknown	SEL 810A and Varian 620i with 8K Core Each	44

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
Lockheed Aircraft Corp. Sunnydale, Calif. Lockheed Crew Systems Simulation Laboratory. Integrated Display Simulator	Integrated display presentations for manual vehicle control, sensor data processing, and situation display applications	Fixed Base	Integrated cathode ray tube display presented at the crew station in raster scan format	SEL 810A and Varian 6201 with 8K Core Each	44
Lockheed Aircraft Corp. Marietta, Georgia Lockheed Flight Simulation Laboratory. VTOL/STOL Simulator	To obtain stability and control information and establish bases for design of flight controls and stability augmentation	Fixed Base	Direct viewed front-projected system by closed circuit TV of the terrain map	Analog and Hybrid Computers (MAC 16 linked through four Astrodata Intracoms to four CI 5000 Analog Consoles) SD-80 Computer, an EAI 131-R, and Solid State Analog Computer Elements.	48
Lockheed Aircraft Corp. Marietta, Georgia Lockheed Flight Simulation Laboratory. Large Transport Simulator	To obtain stability and control information and establish bases for design of flight controls and stability augmentation	Fixed Base	Closed circuit TV visual scene that is back-projected onto a translucent screen and viewed through virtual imaging lens	Analog and Hybrid Computers (MAC 16 linked through four Astrodata Intracoms to four CI 5000 Analog Consoles) SD-80 Computer, an EAI 131-R, and Solid State Analog Computer Elements.	48
Lockheed Aircraft Corp. Burbank, Calif. Lockheed Flight Training Simulator	Primarily for training of airline customer pilots of Lockheed L-1011 aircraft	Motion Base 6-DOF	Variable anamorphic motion picture visual system	Two XDS SIGMA II Digital Computers and one Honeywell Satellite	52
LTV Aerospace Corp. Dallas, Texas LTV Flight Simulation Facilities. Air Combat Simulator	Evaluation of aircraft and aircraft armament systems in close-in visual air combat environments	Fixed Base (Two Separate Cockpits)	Computer generated visual display directly projected on the surface of a 16 ft dia. spherical projection screen surrounding each cockpit	Four General Purpose Digital (two XDS 930 and two SIGMA 5), six Analog/Digital Linkage Systems and six Electronic Associates Inc. Analog Consoles	54
LTV Aerospace Corp. Dallas, Texas LTV Flight Simulation Facilities. Carrier Approach Simulator	To investigate the handling qualities of an aircraft on the carrier approach from glide slope intercept to touchdown	Motion Base (Three Angular DOF Plus One Redundant Degree)	Computer generated image viewed through a collimating lens system on a shadow mask color cathode ray tube mounted above the instrument panel	Four General Purpose Digital (two XDS 930 and two SIGMA 5), six Analog/Digital Linkage Systems and six Electronic Associates Inc. Analog Consoles	54

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
LTV Aerospace Corp. Dallas, Texas LTV Flight Simulation Facilities. Mission Simulator (A-7 Airplane)	To evaluate the compatibility and functional capability of new avionics systems, cockpit layout, and pilot under a simulated mission environment	Fixed Base	Out-of-the-window collimated display of an austere-stylized-ground plane written in a light pencil on a black background	Four General Purpose Digital (two XDS 930 and two SIGMA 5), six Analog/Digital Linkage Systems and six Electronic Associates Inc. Analog Consoles	54
LTV Aerospace Corp. Dallas, Texas LTV Flight Simulation Facilities. Large Amplitude Moving Base (Becomes Operational During Mid-1971)	Investigation of a wide variety of flight simulation tasks	Moving Base (Large Amplitude) 5-DOF	Unknown	Four General Purpose Digital (two XDS 930 and two SIGMA 5), six Analog/Digital Linkage Systems and six Electronic Associates Inc. Analog Consoles	54
Martin Marietta Corp. Denver, Colorado Martin Space Operations Simulation Laboratory.	Evaluation of manned space maneuvering units, EVA, IVA, space to ground tracking, space to space tracking, rendezvous and docking	Motion Base 6-DOF	Out-of-the-window scene	Two Computer Systems. (One system contains four EAI 231-R and the other three EAI 8800 Analog and one EAI Digital)	62
McDonnell Douglas Corp. St. Louis Missouri McDonnell Douglas Flight Simulation Laboratory. Manned Air Combat Simulator	Evaluation of manned performance of proposed weapon systems, flight controls, cockpit arrangement and displays, fighter gun and missile effectiveness, and development of new tactics for fighter aircraft. Used to evaluate handling qualities, establish design goals and to assess dynamic wing and tail loads	Fixed Base (Two Separate Cockpits)	High resolution virtual image projection in the forward 60 deg field of view of the target and horizon through a collimating lens system. Outside the forward 60 deg field of view, the target image is projected on the interior of a 20 ft dia. spherical projection screen by one of two real image projection systems to provide complete 360 deg cockpit visibility. Outside the forward 60 deg field of view, attitude cues (horizon) are provided by means of a three axis gimbal color horizon generator.	CDC 6600 Digital Computer System, one MILGO 4100 Analog Computer, an ADAGE 784 Hybrid Interface Link, and a 1700 Digigraphics Display System	66

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
McDonnell Douglas Corp St. Louis, Missouri McDonnell Douglas Flight Simulation Laboratory. Variable Geometry Simulator	Evaluation of manned perfor- mance of proposed weapon systems, flight controls, cockpit arrange- ment and dis- plays, fighter gun and missile effectiveness, and development of new tactics for fighter air- craft. Used to evaluate handling qualities, estab- lish design goals and to assess dynamic wing and tail loads	Fixed Base	High-resolution rear projected target and horizon onto a trans- lucent screen in front of the pilot, filling his forward 60 deg field of view. Outside the 60 deg forward view, gim- balled spot and horizon projectors are used to indicate the target and hori- zon.	CDC 6600 Digital Computer System, one MILGO 4100 Analog Computer, an ADAGE 784 Hybrid Interface Link, and a 1700 Digigraphics Display System	66
McDonnell Douglas Corp St. Louis, Missouri McDonnell Douglas Flight Simulation Laboratory. Moving Base Simulator	Evaluation of advanced tactical fighter and spacecraft de- signs. Evalua- tions include handling and flying qualities and flight, trim, and power control systems. Simula- tions include pilot induced oscillations, gust, and turbu- lent loading. Accommodates pre- cision tracking and terrain following studies	Motion Base (Large Ampli- tude) 5-DOF	TV monitor viewed through collimating lens. Any of a number of visual displays may be patched into the visual system for pilot viewing.	CDC 6600 Digital Computer System, an ADAGE 784 Hybrid Interface Link, and a 1700 Digigraphics Display System	66
McDonnell Douglas Corp St. Louis, Missouri McDonnell Douglas Flight Simulation Laboratory. Space Shuttle Fixed Base Simulator	Engineering de- sign evaluation of instruments and displays, subsystem manage- ment, human factors, flight controls, soft- ware development for onboard com- puter, and vendor hardware	Fixed Base	Rear projection, real image, out-of- window display system, providing the pilot with a forward 60 deg field of view	CDC 6600 Digital Computer System, an ADAGE 784 Hybrid Interface Link, and a 1700 Digigraphics Display System	66

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
McDonnell Douglas Corp Houston, Texas McDonnell Douglas Houston Operations Simulation Facility. Command Module Docking Simulator	Analysis of docking perfor- mance, control, in-flight opera- tions, and hard- ware.	Fixed Base	Out-of-window visual docking cues pro- vided by a closed circuit television system	Hybrid Computer (CDC 3200 Digital, EAI 131-R Analog Computer, and an ADAGE 660 Hybrid Interface Link)	72
McDonnell Douglas Corp Houston, Texas McDonnell Douglas Houston Operations Simulation Facility. Apollo Telescope Mount Software Simulator	Familiarization of Skylab astro- nauts with the Apollo telescope mount software system and evalu- ation of the man- machine interface	Fixed Base	Unknown	Hybrid Computer System (CDC 3200 Digital, EAI 131-R Analog Computer, and an ADAGE 660 Hybrid Interface Link)	72
McDonnell Douglas Corp Long Beach, Calif. McDonnell Douglas Systems Simulation Laboratory	Real time closed loop simulation studies plus a large variety of analytical studies	Unknown	Color television monitors and colli- mating lens systems affixed to the cockpits for presen- tation of the forward view to the pilot and copilot	Hybrid Computing Facility (XDS SIGMA 5 Digital and two MILGO 4100, seven CI 175, and two Beckman 2132 systems)	76
North American Rockwell Corp. Columbus, Ohio NAR Engineering Simulation and Computing Laboratory. Visual Flight Simulator	VTOL aircraft simulation, lunar landings, TV- guided missile studies, and carrier-approach investigations	Fixed Base	Closed circuit TV of three-dimensional terrain models pro- jected on a screen which is visible to the pilot.	Analog/Hybrid Computing Facility (DDP-19, DDP-24, and EAI 8400 Digi- tal and BB-1100 and EAI 231-R Analog)	118
North American Rockwell Corp. Columbus, Ohio NAR Engineering Simulation and Computing Laboratory. Tactical Weapons Simulator	Evaluation and development of air and space vehicular sys- tems. Includes the simulation of internal and ex- ternal environ- ments and motion dynamics related virtually to any vehicular system	Fixed Base	Closed circuit TV of three-dimensional terrain models pro- jected on a screen which is visible to the pilot	Analog/Hybrid Computing Facility (DDP-19, DDP-24, and EAI 8400 Digital and BB-1100 and EAI 231-R Analog)	118
North American Rockwell Corp. Columbus, Ohio NAR Engineering Simulation and Com- puting Laboratory. Four-Degree-of-Freedom Dynamic Flight Simulator	Simulation of manned and un- manned vehicle real time motion dynamics	Motion Base 4-DOF	Moving displays using TV, film, or slides provided on an external screen or television monitor	Analog/Hybrid Computing Facility (DDP-19, DDP-24, and EAI 8400 Digital and BB-1100 and EAI 231-R Analog)	118

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
North American Rockwell Corp. Los Angeles Calif. NAR Flight and Systems Simulation Laboratory. G-Seat Simulator	Investigation of human factors in acceleration and vibratory environments	Motion Base (Vertical) 1-DOF	Unknown	Hybrid Computer Facility (XDS 9300 Digital and eight General Purpose Analog Computers)	122
North American Rockwell Corp. Los Angeles Calif. NAR Flight and Systems Simulation Laboratory. HOTRAN Simulator	To study hover and transition phases of verti- cal takeoff and landing aircraft plus the entire range of tactical aircraft	Motion Base 3-DOF	Closed circuit television display of terrain models, horizon, and target images	Hybrid Computer Facility (XDS 9300 Digital and eight General Purpose Analog Computers)	122
North American Rockwell Corp. Los Angeles, Calif. NAR Flight and Systems Simulation Laboratory. Transport Aircraft Simulator	To determine the validity of using motion base simu- lation to predict jet transport landing impact characteristics. Also used for analyzing han- dling qualities, controls and dis- plays, and V/STOL transport characteristics	Motion Base (Pitch & Roll) 2-DOF	Closed circuit television display of terrain models, horizon, and target images	Hybrid Computer Facility (XDS 9300 Digital and eight General Purpose Analog Computers)	122
North American Rockwell Corp. Downey, Calif. NAR Flight Simulation Laboratory. Apollo-Type Simulators (Two Separate Command Modules)	Unmanned or man- in-the-loop simulation of vehicle charac- teristics and major subsystems	Fixed Base	Closed circuit TV system presenting Earth, star field, moonscape, and rendezvous-vehicle scenes. One command module has a sextant telescope visual display	Digital/Analog Computer System (XDS 9300 Digital and 12 EAI 231-R, three EAI TR-48, one Beckman 300, and two EAI 350 Digital Operations Systems	126
North American Rockwell Corp. Downey, Calif. NAR Flight Simulation Laboratory. Dynamic Motion Simulator	For imparting dynamic motion to guidance system inertial sensors or an inertial platform	Motion Base 3-DOF	Unknown	Digital/Analog Computer System (XDS 9300 Digital and 12 EAI 231-R, three EAI TR-48, one Beckman 300, and two EAI 350 Digital Operations Systems	126
Teledyne Ryan Aeronautical Company San Diego, Calif. Teledyne Ryan Flight Simulation Laboratory	Development and use of 6-degree- of-freedom simu- lations for engineering eval- uation, pilot training, and hardware studies	Unknown	Unknown	EAI 8400 Digital and one 231-R GPAC, one 8800 GPAC, and five 31R GPAC Ana- log Complement	130

B. FLIGHT SIMULATORS (Industry Owned) (Continued)

Organization Location Facility Name Simulator Name	Purpose	Motion System	Type Visual Presentation	Computer Systems	Page
United Aircraft Corp. East Hartford, Conn. UARL V/STOL Moving Base Simulator	For realistically appraising the performance of pilot-vehicle dynamics for proposed V/STOL aircraft systems and subsystems	Motion Base 6-DOF	TV monitors mounted in the windshield presenting real world display to simulate VFR flight. Advanced IFR displays are pre- sented on 9-inch TV monitors mounted in the instrument panel	Digital Equipment Corporation PDP-6 Computer and two Beckman 1100 Series and one Beckman 2133 Series Analog Computers	132

C. SIMULATION FACILITIES

AIR FORCE CREW STATION SIMULATION FACILITY

REPORTING INSTALLATION: United States Air Force Aeronautical Systems Division Deputy for Engineering Wright-Patterson AFB, Ohio 45433	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Personnel Subsystems Branch (ASD/ENCCP)
OTHER SOURCES OF INFORMATION: Crew Station Simulation Facility Mr. R. Geiselhart Phone: (513) 255-4258	LOCAL OFFICE TO CONTACT FOR INFORMATION: Personnel Subsystems Branch P. T. Kemmerling, Jr., Major, USAF Phone: (513) 255-2314

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Crew Station Simulation Facility (CSSF) is used as a human engineering tool to assist the systems engineer during weapon system development and implementation. The engineer is frequently called upon to make decisions concerning hardware, feasibility and system design problems when little or no information is available to him on total system performance with the human operator in the loop. The facility is organized to provide timely answers to such problems. It is composed of three digital computers, three crew station simulators, three motion platforms, two terrain maps, one TV-type landmass, one radar landmass, a digital target generator and other associated hardware.

Any or all of the computers can be connected to any of the crew station simulators. Two of the crew stations can be operated simultaneously.

The crew stations are full-scale replicas of the FB-111A, C-135B and F-4D cockpits and each can be modified to other configurations within limits. As an example, the pilot's station (instrument panel) of the C-135B is presently configured as that of the C-5A.

COMPUTERS: A SIGMA 5 and two Singer/Link MARK I digital computers comprise the basic computational group. The SIGMA 5 is the primary system, comprising three parallel central processors with 131,072 words of core memory and four Input/Output processors. Each MARK I has one central processor, two data retrieval systems and 64,000 words of program memory. One MARK I is presently in parallel with the SIGMA 5 to provide simultaneous real time dynamics for two cockpits. The second MARK I is used for systems expansion as needed, with all three communicating in real time. A RCA-703 is the basic central processor of the digital target generator (DTG) and is linked directly to the SIGMA 5.

The converters (analog-to-digital and digital-to-analog) are completely modularized for ease of expansion. The controllers and addressing capability are present, and only additional backplates need to be added.

MOTION PLATFORMS: All three crew station cockpit simulators are on motion platforms. The FB-111A has a 5 degree of freedom system with the following characteristics.

Angular pitch - 25 degrees of nose up
 15 degrees of nose down
Angular roll - 10 degrees of left and right roll
Angular yaw - 5 degrees of left and right yaw
Vertical translation - 0 to plus 24 inches
Lateral translation - plus and minus 6 inches

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$400	CONSTRUCTION YEAR: 1966 COST \$ 100,000 ESTIMATED REPLACEMENT VALUE \$11,000,000
CONTRACTOR: ASD, Deputy for Engineering LOCATION: Wright-Patterson AFB, Ohio IMPROVEMENTS AND COSTS: (1966-70) F-111 simulator, Cost \$2,800,000; (1968) C-135B simulator, Cost \$1,200,000; (1968) F-4C cockpit, Cost \$400,000; (1970) FB-111A simulator, Cost \$5,600,000; (1969) F-111A visual system, Cost \$1,000,000.	
NOTE: These items were obtained as surplus and cost figures are replacement value rather than original value.	

PLANS FOR FACILITY IMPROVEMENTS:

MOTION PLATFORMS (CONTINUED)

The other two platforms have three degree of freedom systems with the following characteristics.

Angular pitch - 25 degrees of nose up
 15 degrees of pitch down
Angular roll - plus or minus 9 degrees of roll
Vertical translation - plus or minus 12 inches

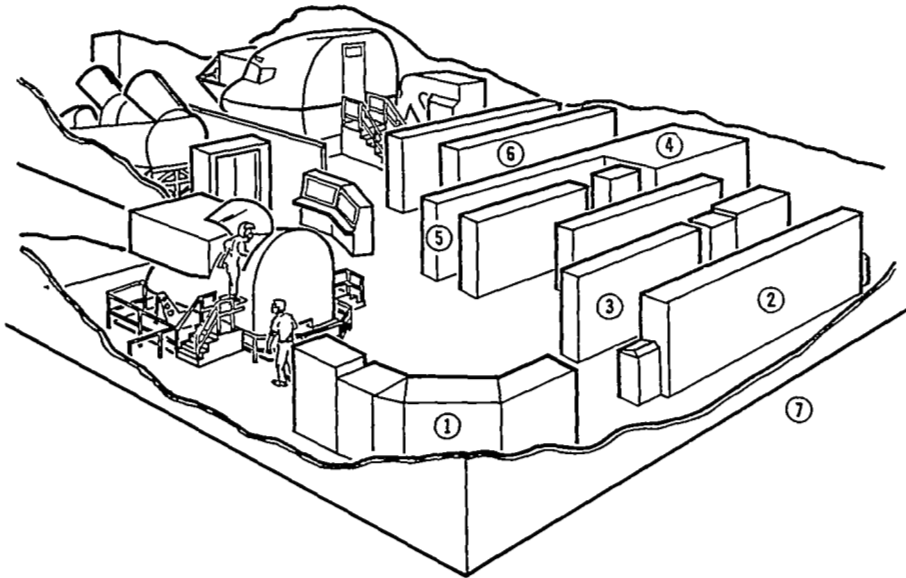
Both motion bases have the following acceleration capabilities.

Pitch - $50^\circ/\text{sec}^2$
Roll - $50^\circ/\text{sec}^2$
Vertical - $\pm .8g$ of normal $1g$

VISUAL SYSTEMS: The basic visual support package consists of two moving model systems (modified SMK-23's) and one photographic scanning system. The SMK-23's are three-dimensional: one is 12000:1, used for low level navigation, and the other 3000:1, used for TO's and landings. Closed circuit television is used to pick up the visual and display it through collimating lenses to the pilot in the cockpit. This is a 1000-line black-and-white system. The photographic scanning system uses two photographic plates that present the visual scene and its elevation information. This is a 525 line black-and-white TV system that can be presented to the pilot.

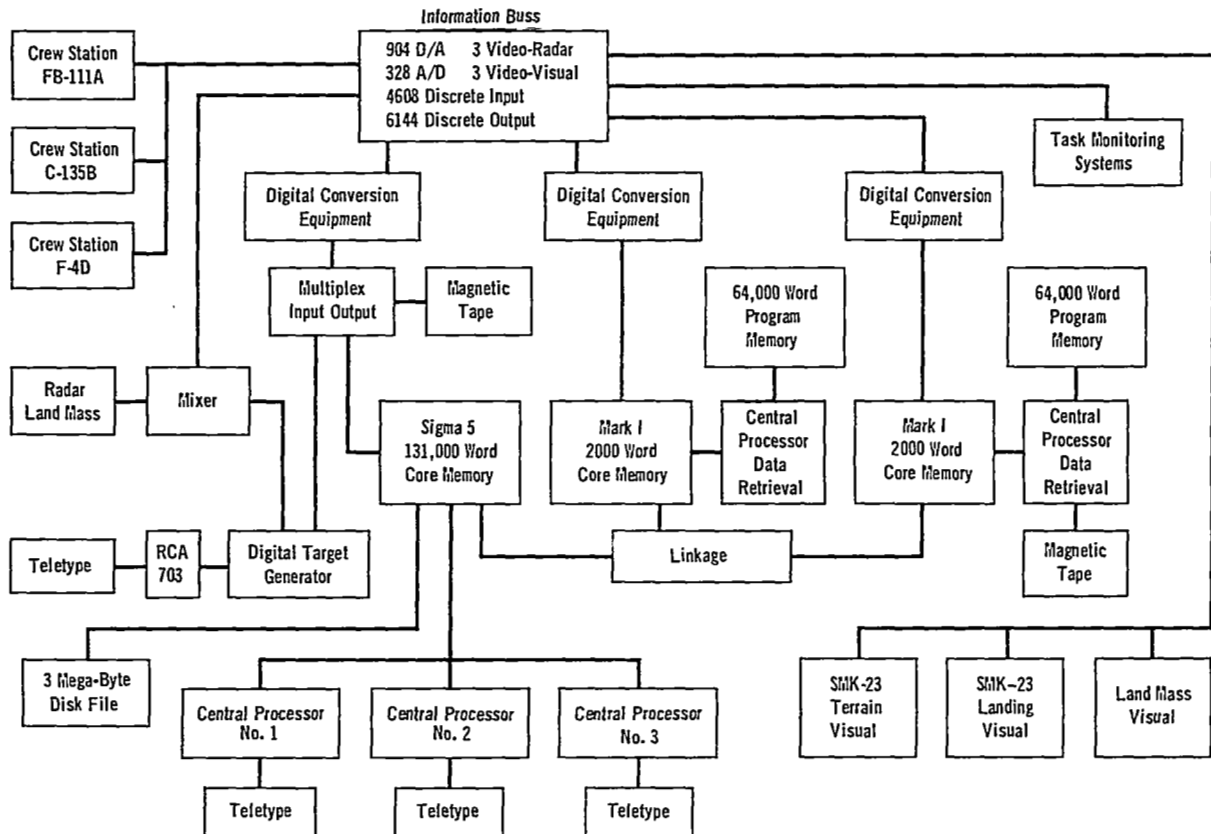
RADAR: There are three radar systems that can be simulated in precise detail. The systems, attack radar, terrain following and avoidance radar and the radar homing and warning, comprise the basic support package. They can be modified in both display and mode functions to simulate systems under analysis.

FACILITY LAYOUT



1. Experimenter's Area
2. SIGMA 5
3. Digital Target Generator
4. Land Mass
5. MK-I
6. MK-I
7. Visual Systems (Not Shown, They are External to the Vault)

OPERATIONAL DIAGRAM



AIR FORCE DYNAMIC ENVIRONMENT SIMULATOR

REPORTING INSTALLATION: United States Air Force Aerospace Medical Research Laboratory Wright-Patterson AFB, Ohio	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Aerospace Medical Research Laboratory
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: AMRL (EMS), Area B, Bldg 33 Wright-Patterson AFB, Ohio

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Dynamic Environment Simulator is a 19 ft radius, double gimballed human centrifuge. The main arm is capable of rotating at 55 rpm, which produces a 20g field. The 10 ft diameter spherical cab may be rotated or oscillated up to 50 rpm while the fork axis is capable of 30 rpm. Provision also exists for controlling the climatic and atmospheric conditions within the cab. A removable vibration platform is under development.

The control system uses a PDP-1 digital computer and provides for manual, automatic, or closed loop operation. Approximately 200 slip ring connections are available for instrumentation.

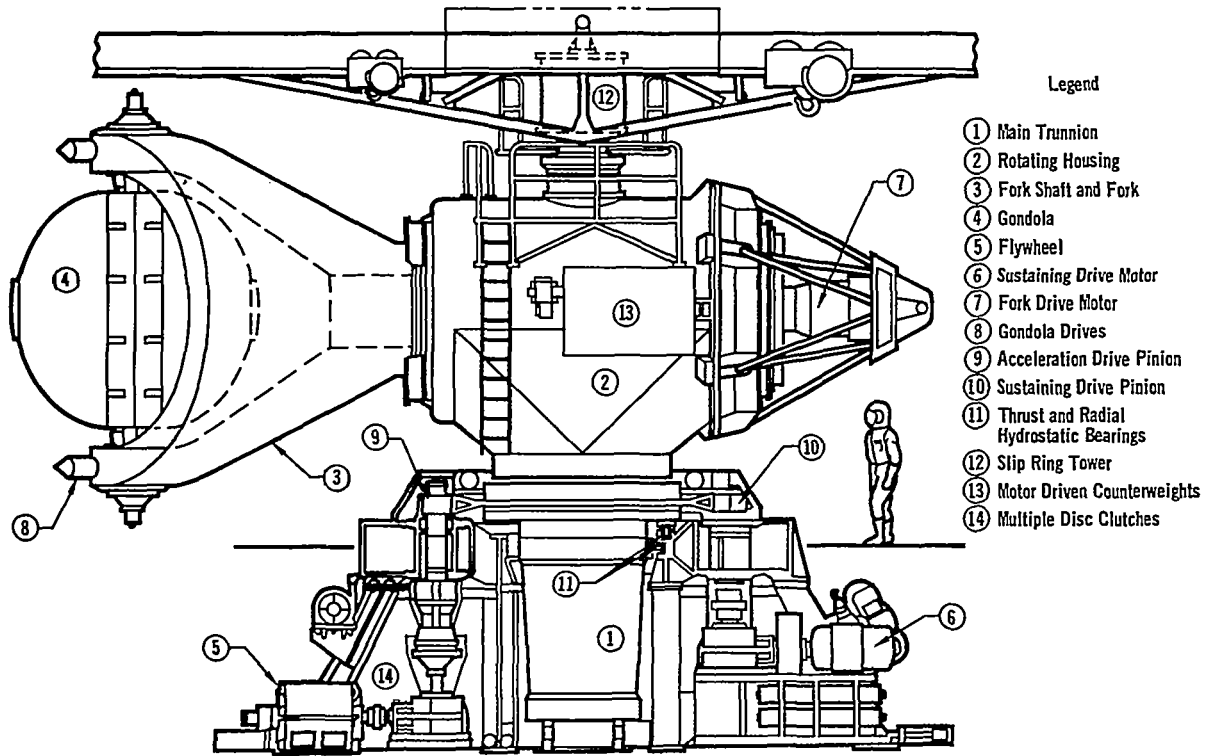
TESTING CAPABILITIES: This facility provides for the simultaneous simulation of most of the stresses encountered by aircrew members during flight and escape maneuvers.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT) \$1,500	CONSTRUCTION YEAR: 1962-68 COST \$ 6,500,000 ESTIMATED REPLACEMENT VALUE \$12,000,000
CONTRACTOR: Franklin Institute	LOCATION: Philadelphia, Pa.
IMPROVEMENTS AND COSTS: (1968-69) General development and reliability improvements, Cost \$200,000.	

PLANS FOR FACILITY IMPROVEMENTS: Upgrade system performance; develop closed loop combat maneuvering simulations.

FACILITY LAYOUT



Dynamic Environment Simulator

OPERATIONAL DIAGRAM

Not Available

AIR FORCE SIMULATION AND TRAINING MEDIA DEVELOPMENT SYSTEM

REPORTING INSTALLATION: Air Force Human Resources Laboratory Brooks Air Force Base Texas	STATUS OF FACILITY: Standby for Modification COGNIZANT ORGANIZATIONAL COMPONENT: Advanced Systems Division, USAF
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Resources and Instrumentation Branch WPAFB (N. Schwartz) AF HRL (TRI) Phone: (513) 255-5910

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Simulation and Training Media Development System is a laboratory complex for conducting exploratory development in the areas of simulation techniques, instructional media and training innovations. It is composed of an ME-1 instrument trainer modified to closely resemble the cockpit of a T-37 aircraft. The cockpit has a roll and pitch motion base. The trainer, formerly driven by a special-purpose analog computer, is being modified to be driven by a digital computer. A TV visual display can be provided on a TV monitor mounted on the cockpit. The visual display is provided by a modified SMK-23 Visual Simulator Trainer Attachment, consisting of a three-dimensional model which is viewed by a 1000-line TV camera. The model represents an airfield and surrounding terrain features. This model is mounted on an endless belt which is servo driven for the longitudinal motion of the aircraft. The television camera views the model through an optical probe. This probe is servoed to provide the rotational motions of azimuth, roll and pitch of the aircraft. The probe and television camera are mounted on a servoed platform, which moves across the model for latitudinal movements, and in and out from the model to simulate altitude.

The modifications to drive the simulator from a digital facility are scheduled to be completed in July of 1971.

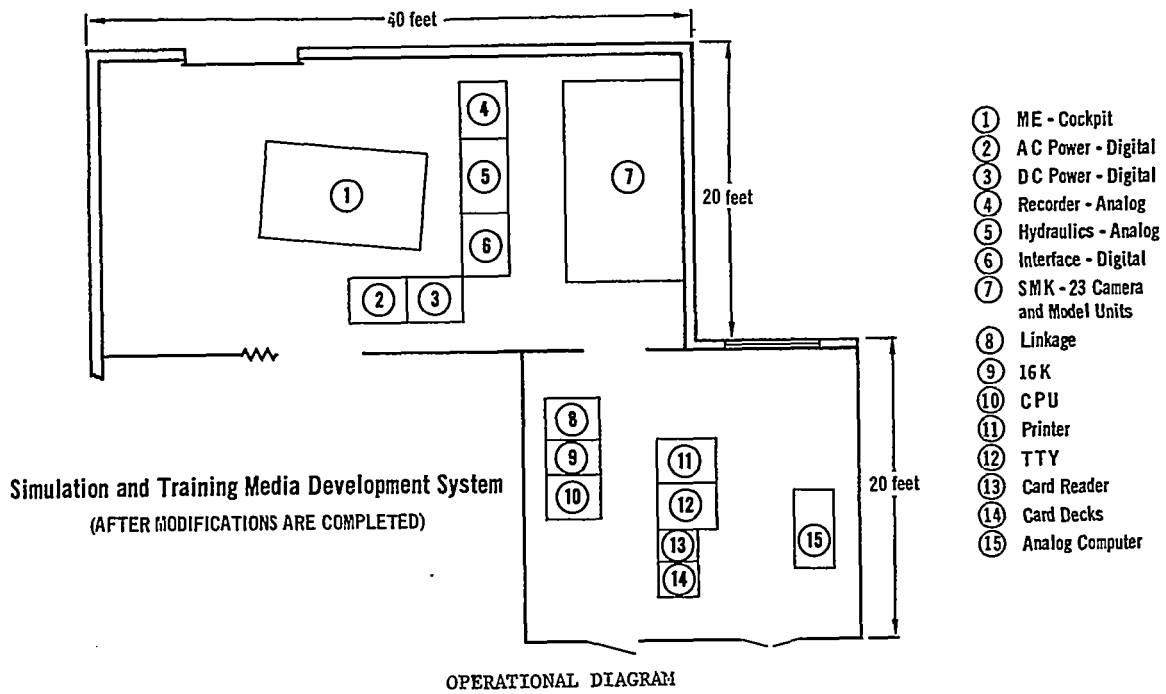
The computing facility will consist of an XDS SIGMA 5 computer with a 16,000 word magnetic core memory. Computer words will be 32 bits. Peripheral equipment will include a medium-speed line printer, and card punch and reader.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$200	CONSTRUCTION YEAR: 1969 ESTIMATED REPLACEMENT VALUE \$750,000
CONTRACTOR: Internally Constructed IMPROVEMENTS AND COSTS:	LOCATION:

PLANS FOR FACILITY IMPROVEMENTS: Replace analog computers with digital equipment, and install 140° wide-angle optical probe and associated TV modifications.

FACILITY LAYOUT



Not Available

BELL VISUAL SIMULATION FACILITY

REPORTING INSTALLATION: Bell Aerospace Company, Division of Textron P.O. Box 1 Buffalo, New York 14240	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Electronic Data Processing Department
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Electronic Data Processing Department R. E. Carroll, Dept 181, Mail Zone C-6 Phone: (716) 297-1000, ext 7196

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The visual simulation facility provides displays and visual aids for man-in-the-loop projects. Equipment in the visual simulation facility can be electronically coupled with the analog computers and cockpit consoles to provide a wide variety of simulated space, lunar, and earth environments. Image generation equipment includes a six-degree-of-freedom camera-model-track consisting of a TV camera and optical probe mounted on a gantry system. Images of scaled terrain and vehicle models can be transmitted via closed circuit television to a back-projected screen in front of a pilot cockpit station. Starfields and constellation patterns can be generated with a planetarium and superimposed onto the camera-model-track image for realistic background effects. An electronic image generator produces stereo images which, when used with polarized glasses, provides depth image perception.

HYBRID COMPUTER COMPLEX:

Analog - The present configuration features one TR-48 and three Electronic Associates Pace 231-R analog consoles, together with two Applied Dynamics AD-4 analog/hybrid computers. The 231-R equipment complement includes 324 operational amplifiers (72 are integrators), 320 potentiometers, 42 comparators, 42 electronic multipliers, 14 servo multipliers, 14 resolvers and 34 diode function generators. The EAI TR-48 contains solid-state circuitry with 58 operational amplifiers. Each AD-4 hybrid computer consists of 336 operational amplifiers (including 64 integrators), and 200 servo-set potentiometers. Nonlinear equipment includes 60 electronic multipliers and 20 diode function generators. An independent logic patchboard consists of 24 comparators, 72 logic gates, 24 flip-flops, and 24 track and store networks. Observation of analog output is effected by modern strip-chart recorders and X-Y plotters.

Digital - The IBM 7090 computer is the principal processor in the hybrid computing facility. Its chief attributes are solid-state circuitry, a random access memory with a capacity of 32,768 words, and a CPU cycle time of 2.18 microseconds. Accessed through two data channels is a complement of peripheral equipment which includes 12 magnetic tape drives, a printer, a card reader and a direct data connection for special input/output devices such as linkage to the analog computing system.

Hybrid Interface - Three hybrid interface systems are available. The first consists of 15 A/D channels, 20 D/A channels, 10 discrete sense lines and an interrupt timer. This system, developed entirely by Bell, links the analog machines to the digital computer for transmission of 14-bit data words (including sign). Data conversion times (125 microseconds A/D and 10 microseconds D/A) are included in the total (minimum) transmission times of 220 microseconds A/D and 120 microseconds D/A and permit transfer rates of over 4000 words per second A/D and 8000 words per second D/A.

The two faster AD-4 hybrid interface systems each consist of 16 D/A channels and 16 A/D channels. Data words are 16 bits long with transmission rates of 90 microseconds A/D and 80 microseconds D/A. An advanced addressing scheme enables the digital computer to access any amplifier, trunk, coefficient device or diode function generator. Analog control, logic modes of operation, and integrator time

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$5,000	CONSTRUCTION YEAR: 1966 COST \$ 753,000 ESTIMATED REPLACEMENT VALUE \$1,300,000
CONTRACTOR: Internally Constructed IMPROVEMENTS AND COSTS: (1967) Two AD-4 analog/hybrid computers with A/D and D/A converters, Cost \$410,000.	LOCATION: Buffalo, New York

PLANS FOR FACILITY IMPROVEMENTS: Improve TV system to 1029 line system.

HYBRID COMPUTER COMPLEX (CONTINUED)

scaling can be controlled from the digital portion of the program. The digital program can also be made aware of an analog error condition, such as overload, A/D conversion, or addressing errors.

SIMULATION HARDWARE:

Planetarium - This unit is a 48-inch opaque fiberglass sphere with a television camera mounted within. The surface of the sphere contains small holes at the locations of stars from the first to the fourth magnitude in the celestial sphere, the size of each hole being proportional to the star's brightness.

Horizon Generator - A 525 line black-and-white television system simulates a horizon by use of a camera and oscilloscope.

Terrain Map - The terrain map includes a horizontally mounted gantry system consisting of a TV camera and optical probe. The system was developed for the purpose of generating TV images of terrain and rendezvous models. The map, for example, has been modeled into a 600:1 approximation of the lunar surface; a 50:1 approximation of carrier landings; and a 300:1 approximation of an Air Cushion Vehicle docking. The system has six degrees of freedom.

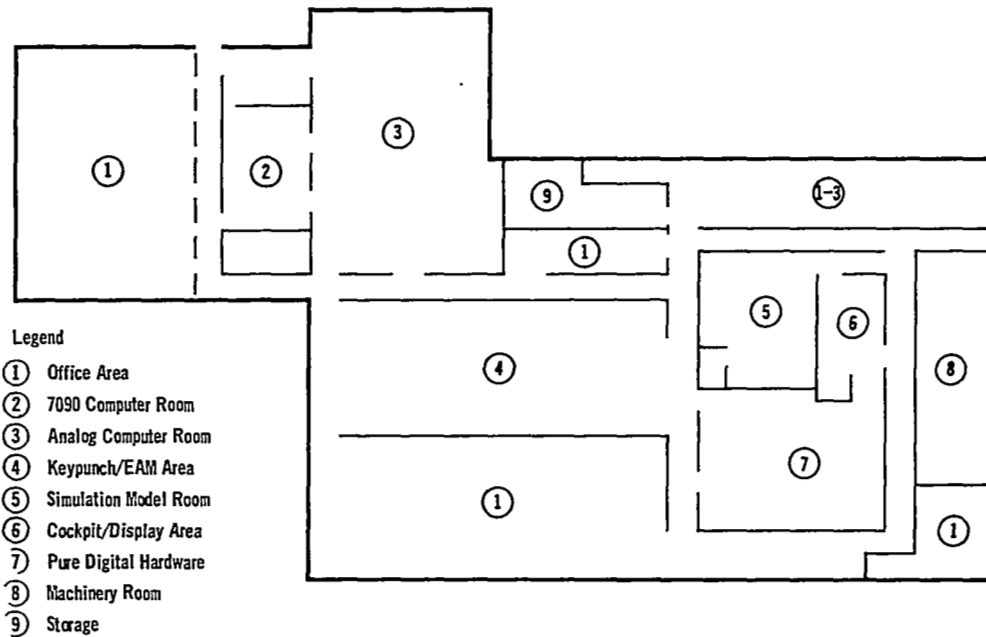
Electronic Image Generator - An electronic image generator is a device that presents two six-degree-of-freedom computer-controlled images of a rectangular parallelepiped on a 9 x 12 foot non-depolarizing back-projecting screen in such a way that through the use of polarized eye glasses, an operator can take advantage of his binocular vision to obtain depth cues, thus aiding him in his range judgements.

Cockpit Simulators - The facility can provide cockpit simulators fitted with a wide variety of pilot controls, including stick, pedals, and throttle, with collective, variable breakout and force gradients; hydraulic feed system; 3-axis side arm controller; mode selectors; indicator lamps; spacecraft rocket thruster controls; specialized Air Cushion Vehicle controls and computer controls, all providing electrical signals proportional to control displacements. Oscillographic and instrument panel components can be readily varied for different configurations of display. Some of the Bell cockpits are fixed base, and others movable base with motions of pitch, roll and yaw angles.

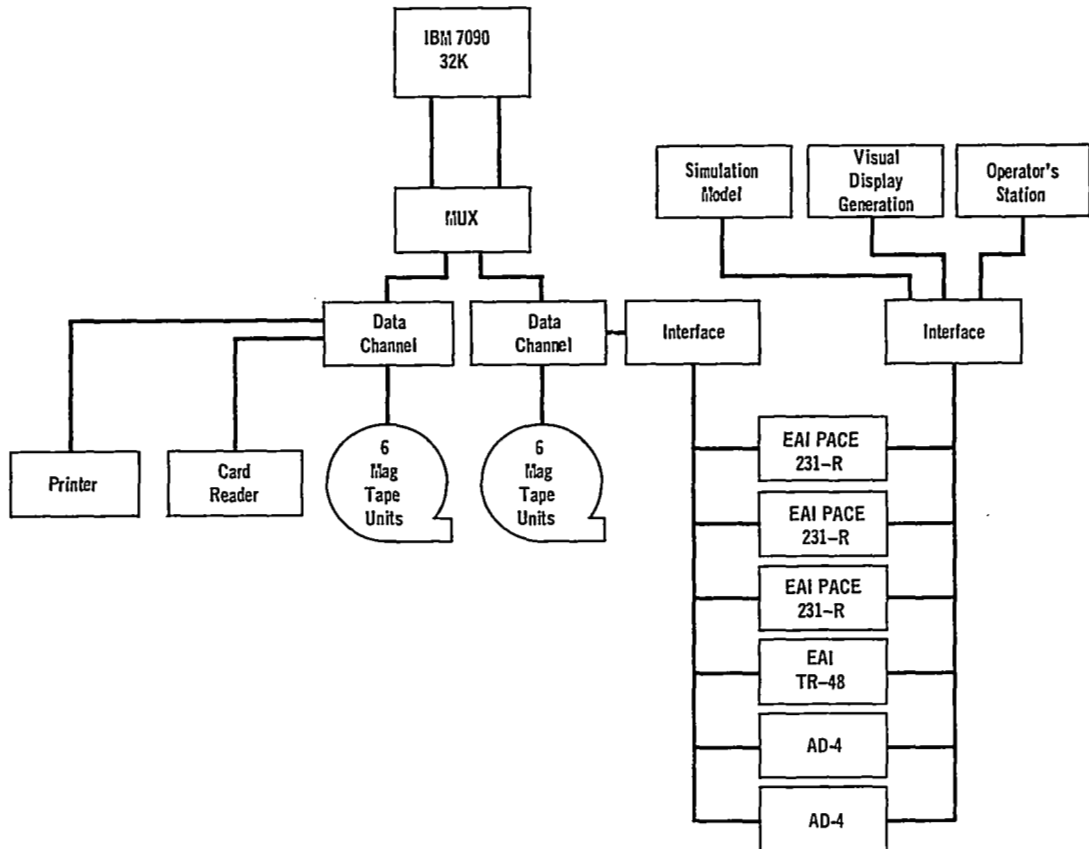
Fixed base cockpit simulators have been used in (1) air cushion vehicle studies with a dynamic out-the-window display of a mother ship against a typical sea, (2) evaluation of maneuvering and control characteristics of a spacecraft in the environment of a mother ship, (3) the energy management of a re-entry vehicle, (4) an all-weather carrier landing system, (5) a VTOL research transport, (6) a lunar landing training vehicle, and (7) a multi-mode airborne helicopter landing system.

Moving base cockpits have been used in simulation studies of an Air Cushion Vehicle. A hydraulically powered operator cabin complete with controls and instrument panel was employed. The cockpit responded to motions of water sideslip (± 45 degrees) and roll (± 12.5 degrees). Several types of moving base cockpits have been used in conjunction with the visual generation equipment to simulate rocket propelled lunar transportation vehicles. One of these was the Manned Flying System flight simulator, which consisted of a one-man seat capable of being hydraulically driven ± 60 degrees in pitching motion, and a horizon generator capable of producing roll and pitch motions of ± 60 degrees each, as well as producing altitude changes. In order to evaluate the handling qualities and control characteristics of the One-Man Lunar Flying Vehicle, various methods of control were simulated in a lunar environment which included kinesthetic control. The operator station was at the intersection of two beams at right angles mounted on a universal joint, so that it could respond to pilot inputs of ± 30 degrees pitch and ± 15 degrees roll. The moments of inertia of the platform could easily be varied by positioning different weights at different locations along the beams. Another part of the same simulations study was the evaluation of manual thrust vector control by utilizing a 3-axis pilot station driven in pitch, roll and yaw. This was used in conjunction with a projected lunar scene from which the pilot derived the three translational cues (down range, lateral and altitude). Since the pilot is an integral part of the control system, the sensing of body motion is an important cue which enables controllability of these vehicles. The 3-axis pilot station provided ± 60 degrees rotation in pitch, ± 180 degrees in yaw, and ± 15 degrees in roll.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



BOEING AEROSPACE VISUAL FLIGHT SIMULATOR

REPORTING INSTALLATION: The Boeing Company P.O. Box 3999 Seattle, Washington 98124	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Aerospace Group, Space Division
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Visual Flight Simulator T. K. Maki, M-S 86-04 Phone: (206) 773-1170

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Visual Simulation Facility features modular components which may be arranged in a variety of different simulation systems. The basic components include a digital computer system, scene models, closed circuit TV visual display system and several fixed based crew stations.

COMPUTER EQUIPMENT: One Xerox Data Systems (XDS) 930 digital computer in conjunction with a Varian 622i digital computer and a Sanders ADDS 900 graphics display system provides the basic computer requirements for the facility. A second XDS 930 has and can be tied into the system if additional capability is required.

The XDS 930 digital computer provides a 16K word core memory, 24-bit word length, 1.925 microsecond memory cycle time, 96 analog input channels from simulator equipment (providing 0.2 percent analog-to-digital conversion accuracy), 192 single bit Boolean or switching inputs to the computer, 108 analog data output channels to simulator equipment (providing 0.2 percent analog conversion accuracy and 12 to 16 bit digital output registers), and 216 single bit Boolean or switching outputs to simulator equipment. Peripheral equipment includes two electric typewriters, two paper tape readers and punch, two card readers, two line printers, magnetic tape units, chart records, and a dual control console with register access and readout capability.

The Varian 622i digital computer characteristics include a 4,096 word core memory, 18-bit word length, 1.8 microsecond memory cycle time, and a timing and signal processing unit which enables this system to operate in conjunction with the XDS 930 computer.

VISUAL DISPLAY SYSTEM: A high resolution closed circuit TV visual display system consists of photo-mechanisms for an optical probe system, three 6-DOF carriages and gimbal systems for transporting TV cameras over various scaled two- and three-dimensional models, globes and aero-photo mosaics; also included is a TV projector with a 30 foot diameter hemispherical screen.

VISUAL SYSTEM MOTION PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	88	2.83	5.25
Velocity (ft/sec)	3.00	.33	.33
Acceleration (ft/sec ²)	.29	.29	.29
Angular Motion	Roll	Pitch	Yaw
Displacement (deg)	Unknown	Unknown	Unknown
Velocity (deg/sec)	60	60	60
Acceleration (deg/sec ²)	60	60	60

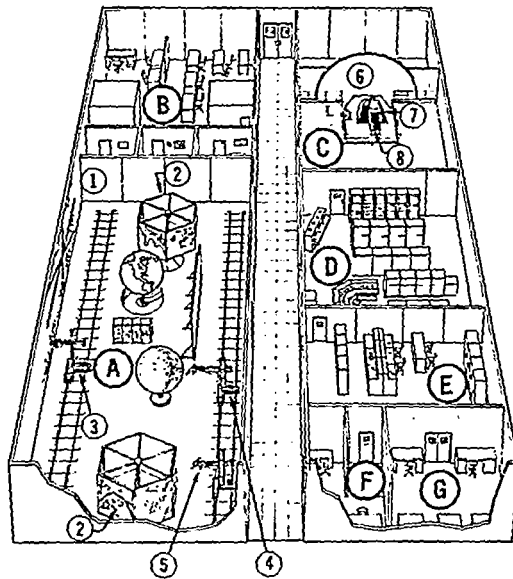
FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1963-65 COST \$ Not ESTIMATED REPLACEMENT VALUE \$ Available
CONTRACTOR: Internally Constructed	LOCATION: Kent, Washington
IMPROVEMENTS AND COSTS: (1966) Keyboard entry, added displays, landing model, two magnetic tape recorder units, SST cockpit; (1967) Collimated light source, aeromosaic model, model update, electronic fog simulator; (1968) Varian 622i computer, servo cable drive, added displays; (1969) Optical probe, high resolution camera, update SST cockpit, add force feel control system, Sanders graphics display, IOVI cockpit.	

PLANS FOR FACILITY IMPROVEMENTS: Add color TV, improve projection system, increase computer capacity, improve remote station capability, add to and improve models.

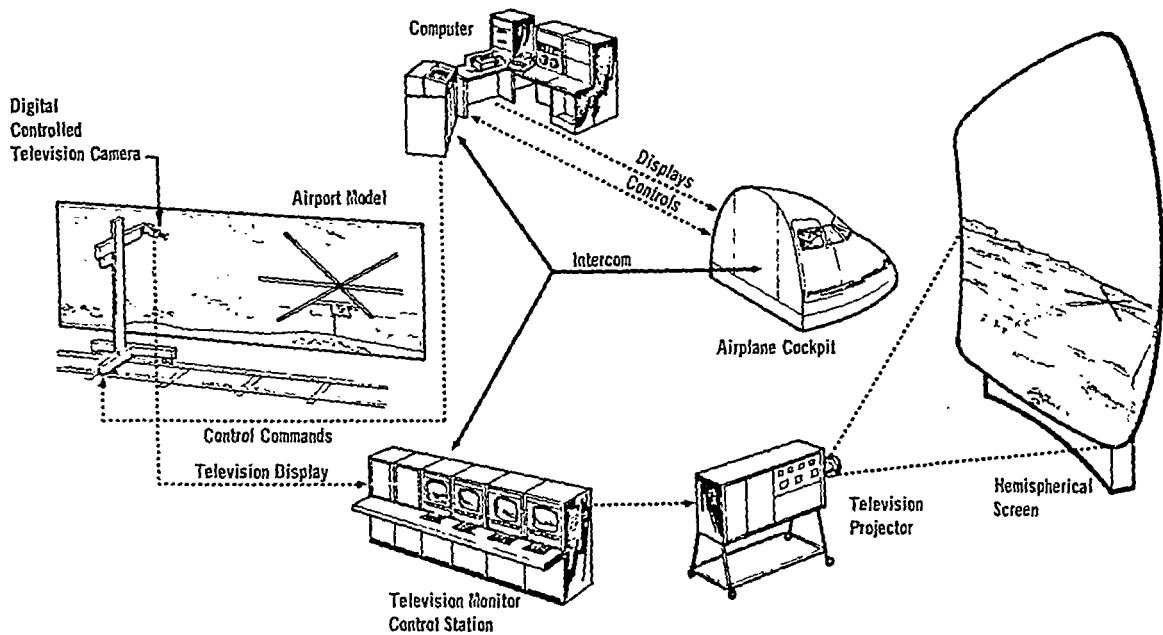
TESTING CAPABILITIES: The Boeing Aerospace Visual Flight Simulator facility is a general-purpose research tool. Uses include development and evaluation of (1) the effect of design configuration changes on aircraft flying qualities, (2) suitability of cockpit or crew station displays and avionics hardware, and (3) a pilot's or astronaut's ability to perform major functions in aircraft or spacecraft flight control, navigation and guidance.

FACILITY LAYOUT



- (A) Model Room
 - (1) Wall Model
 - (2) 6 Model Turret
 - (3) Number 1 Track and Television Carriage
 - (4) Number 2 Track and Television Carriage
 - (5) Number 3 Carriage
- (B) Office Area
- (C) Screen Room
 - (6) 30 Ft Diameter Hemispherical Screen
 - (7) Mock-up Cockpit
 - (8) Television Projector
- (D) Computer Room
- (E) Model Shop
- (F) Clean Room
- (G) Office and Electronics Assembly

OPERATIONAL DIAGRAM



BOEING KENT SIMULATION CENTER

REPORTING INSTALLATION: The Boeing Company P.O. Box 3999 Seattle, Washington 98124	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Boeing Computer Services Northwest District, Orgn. 2-2527
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Kent Simulation Center C. P. Moshier Phone: (206) 773-3033

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Simulation Center at the Boeing Kent Facility provides a variety of modern computer and display equipment. This equipment is highly modular and provides general-purpose use with fixed base crew stations. These include a multistress chamber cockpit for human performance studies in environment of vibration, heat, pressure, noise, illumination and atmosphere. Also provided are an air traffic control center with pilot console and a Space Shuttle Vehicle Cockpit mock-up.

COMPUTER EQUIPMENT:

Digital - An IBM 360/65 system with an IBM 2250 display/communications unit and a general purpose XDS 9300 system with a Differential Equation Solver (SDS DES-1) provide required digital computation at the Center. A Computer Simulator System with 65K, 48-bit core storage is also available and provides hardware-software systems developed to simulate digital or logic systems often found on-board modern aerospace products.

Analog - Four consoles of general purpose EASE Beckman Analog Computer equipment are available, along with an AD-256 solid state system and nine AD-32 small portable analog computers.

Converters - Four AD-4 consoles provide a basis for a new high speed analog system which includes more conversion capability than any other digital-analog linkage system that has been reported in the literature.

Analog/Digigraphics - A man-machine interface (MMI) system displays images on many CRT indicators simultaneously. Displays are generated by means of analog random graphics and digital television. Both the analog and digital graphic generators have image resolutions of 1024 points in the H and V and refresh at 60 Hz. Image elements include characters, symbols, vectors, circles, arc segments and points.

TESTING CAPABILITIES: The Simulation Center is used for system development and evaluation including such products as missiles, hydrofoil boats, spacecraft, boosters, traffic systems, and command control systems.

FACILITY COST HISTORY

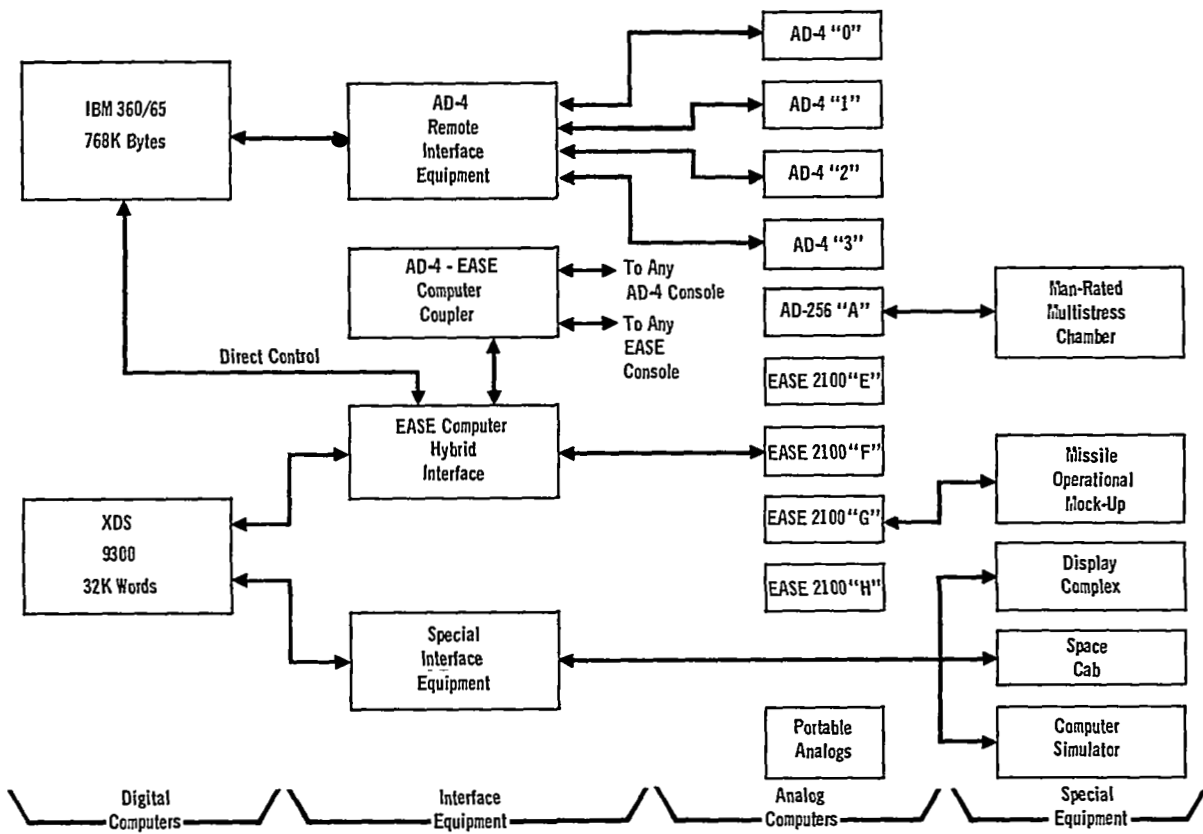
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$1,550	CONSTRUCTION YEAR: 1964 COST \$3,670,000 ESTIMATED REPLACEMENT VALUE \$5,000,000
CONTRACTOR: Internally Constructed IMPROVEMENTS AND COSTS: (1969) Hybrid function generation system (AD-4) hybrid computers, Cost \$800,000.	

PLANS FOR FACILITY IMPROVEMENTS: (1) Expansion of AD-4 hybrid capability, (2) upgrade of digital capability, (3) improvement of display capability.

FACILITY LAYOUT

Not Available

OPERATIONAL DIAGRAM



BOEING VERTOL FLIGHT SIMULATION FACILITY

REPORTING INSTALLATION: The Boeing Company Vertol Division P.O. Box 16858 Philadelphia, Pa.	STATUS OF FACILITY: COGNIZANT ORGANIZATIONAL COMPONENT: Test and Simulation, Organization 7432
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Test and Simulation, Org 7432 E. M. Allen Phone: (215) 522-4099

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Simulation Facility is an integrated laboratory complex for performing unmanned and piloted real-time flight simulation studies of aircraft, control system, and instrumentation concepts and configurations. It is comprised of two laboratories, the Flight Simulator Laboratory and the Hybrid Simulation Laboratory. These two laboratories are located in separate buildings and are interconnected by electrical cabling.

HYBRID SIMULATION LABORATORY: The Hybrid Simulation Laboratory is a modern large scale hybrid computation complex. It is capable of providing simultaneous operation of several hybrid and analog simulations, depending on problem size. The complex is totally state of the art, with recent acquisition of two mini-computers for the purpose of multivariable function generation. It is composed of the following digital and analog equipment.

Digital - An IBM 360/44 system provides 25,600 bytes core memory, 32 priority interrupts, 16 high-speed floating point register, and 2 high-speed and 1 low-speed channels. Also included are two 800 B.P.I. tape transports, a 2311 disk system, two 2315 disk systems, a high-speed card read/punch, a high-speed line printer, two alphanumeric scope/keyboard units, a console typewriter and a ball printer. A Basic Computer Arts Function Generation System provides an inter-data processor with 24,000 byte core, an inter-data processor with 16,000 byte core, two 16-channel analog-to-digital units, two 16-channel digital-to-analog units, and two "read only memory" software systems.

Analog - Four 3/4 expanded Applied Dynamics (AD-4) systems are available with 771 solid state amplifiers, 4 resolver expansions, and 2 display consoles. Other analog equipment includes a .0001 - 10 ufd integrator system in 6 decades, a 1/8 expanded AD-4 maintenance console, 128 channels 100 kc analog-to-digital converters, and 128 channels digital-to-analog converters, as well as four 8-channel brush strip chart recorders, four 8-channel Varian Statos III strip chart recorders, and four X-Y plotters.

FLIGHT SIMULATOR LABORATORY: The Flight Simulator Laboratory contains a six-degree-of-freedom small motion base, a pilot station equipped with an adaptable instrument panel and a wide-range variable flight control force-feel system, a cockpit-mounted out-of-the-window collimated visual-simulation display, a visual simulation scene generating system and associated interface, and control and readout hardware.

The small motion base employs the relatively rigid strut actuator concept. The small travels of the actuators result in approximately uncoupled motion and deliver nudge-type acceleration cues to the pilot of satisfactory validity. Three of the six electro-hydraulic actuator struts are vertical and three are horizontal. The Moog valves of the struts respond to command signals generated from the mathematical model programmed on the hybrid computing system. The cockpit is equipped with a variable flight controls force-feel system and a cockpit mounted out-of-the-window collimated visual display.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT):	No operator response on this item	CONSTRUCTION YEAR: 1965	COST \$ 657,000
		ESTIMATED REPLACEMENT VALUE \$2,500,000	
CONTRACTOR: Internally Constructed		LOCATION: Ridley Twp., Pa.	
IMPROVEMENTS AND COSTS: (1967-69) Hybrid computer facility, Cost \$1,500,000; (1966-68) Variable controls force-feel system, Cost \$60,000; (1968-69) Small motion base 6-DOF system, Cost \$40,000; (1969) Out-of-the-window cockpit visual display, Cost \$5,000; (1970) AD-4 computer interface completion, Cost \$55,000.			

PLANS FOR FACILITY IMPROVEMENTS: Large visual simulation three-dimensional scene generation system.

FLIGHT SIMULATOR LABORATORY (CONTINUED)

The variable flight control force-feel system incorporates actual aircraft flight controls modified with load cells at the points of pilot-applied forces. Force-feel is simulated by hydraulic servo-actuators controlled by computer signals developed from the load cell force signals and control position feedback signals. Any desired relationship between pilot effort and control position can be simulated. The system offers high signal-to-noise ratios, and responds to forces from an ounce to more than a hundred pounds.

The visual display system presents the pilot with a bright symbolic visual scene. The visual scene is computer generated, offering both latitude in scene content and an unconstrained flight path and maneuver capability. The generated scene is reproduced by a 600 line black and white television system for viewing by the pilot through a large collimating lens. The pilot's field of view measures 38 degrees vertically by 53 degrees horizontally.

TESTING CAPABILITIES: This facility permits a wide variety of studies and pilot evaluations of aircraft handling and flying qualities, automatic and manual flight control systems, and design criteria definition for the rapid, economical, manageable, and safe development of aircraft and aircraft systems. The facility is particularly adapted to the study of V/STOL aircraft because of its capability for providing cockpit motion in six degrees of freedom.

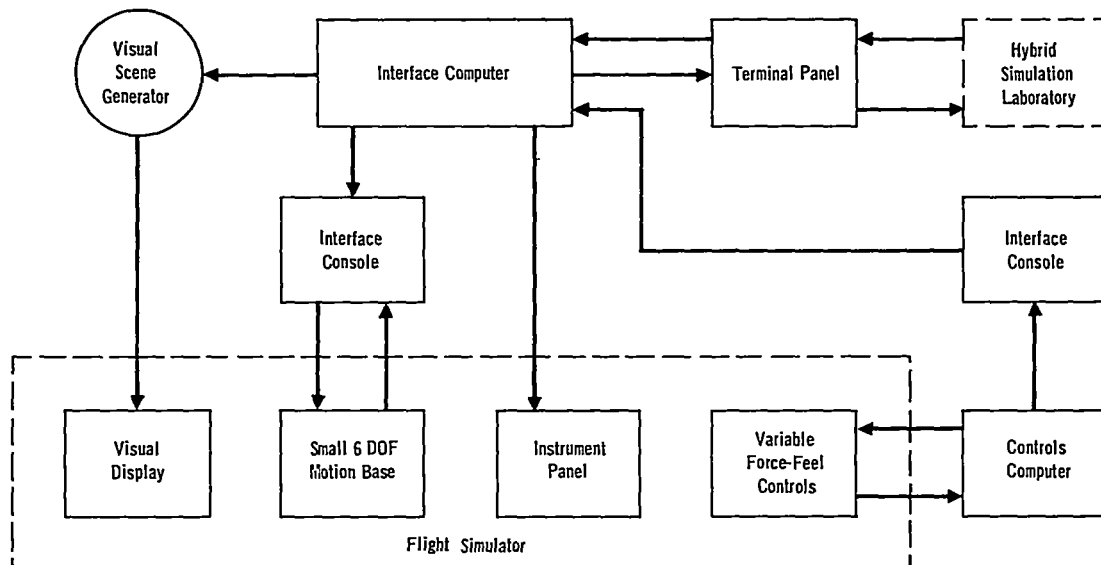
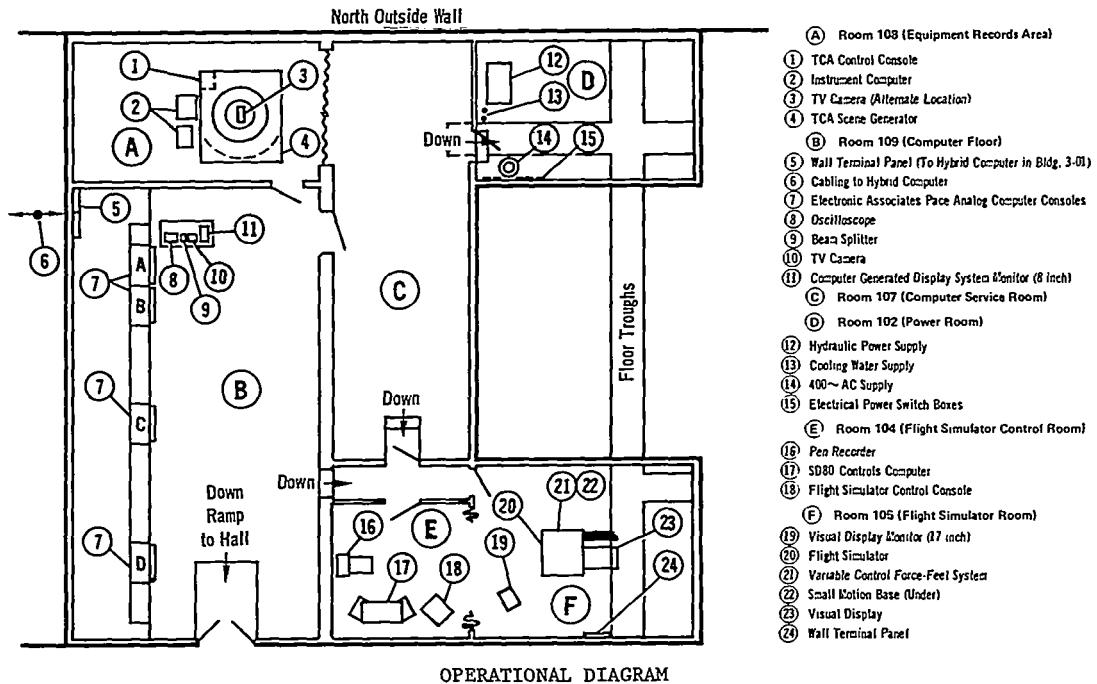
MOTION SYSTEM PERFORMANCE: Payload (including Pilot) = 770 lb.

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	.416	.416	.416
Velocity (ft/sec)	± 3.416	± 2.166	± 2.166
Acceleration (ft/sec ²)	± 35.4	± 64.4	± 28.9
Rotary Motion	Roll	Pitch**	Yaw
Displacement (deg)*	19	13	19
Velocity (deg/sec)	± 97	± 69	± 155
Acceleration (deg/sec ²)	± 414	± 248	± 745

*Stop-to-stop total

**Pitch tilt = 26 deg

FACILITY LAYOUT



FAIRCHILD HILLER FLIGHT SIMULATION LABORATORY

REPORTING INSTALLATION: Fairchild Hiller Corporation Republic Aviation Division Farmingdale, New York 11735	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Engineering Department
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Dynamics D. B. Jordan, Dept 629 Phone: (516) 531-3267

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Simulation Laboratory consists of three basic elements which are an analog computer, cockpit and visual display equipment.

COMPUTER EQUIPMENT: The computer consists of a medium sized analog computer facility capable of modeling the aircraft in six degrees of freedom, including control systems, weapons, thrust, ground effects, etc. Target error in three dimensions is also instrumented.

SIMULATION HARDWARE:

Cockpit - The crew station simulator contains typical display and control equipment fully operative to represent a realistic in-flight environment for the pilot. The cockpit is enclosed and provided with an out-of-the-window visual display.

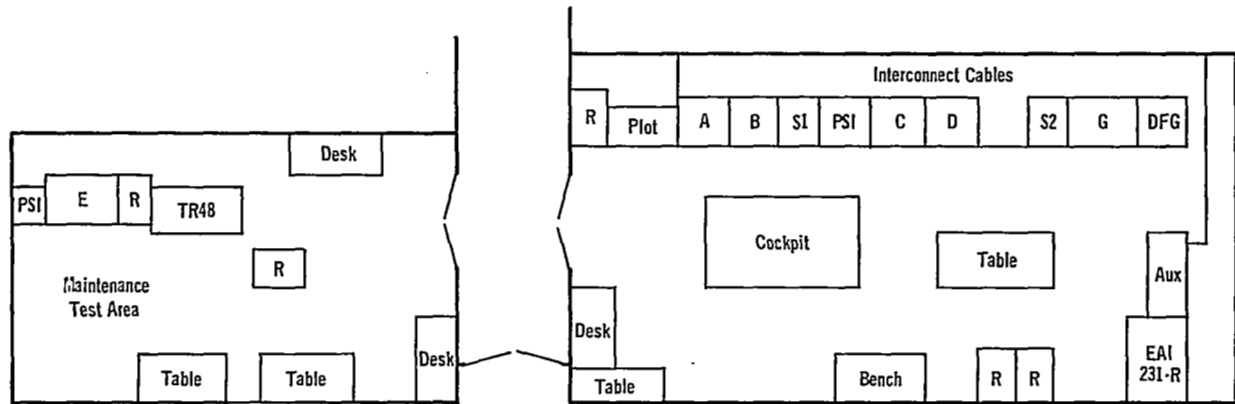
Visual Display - The visual display consists of a large screen scope providing dynamic representations of aircraft attitude and target position.

FACILITY COST HISTORY

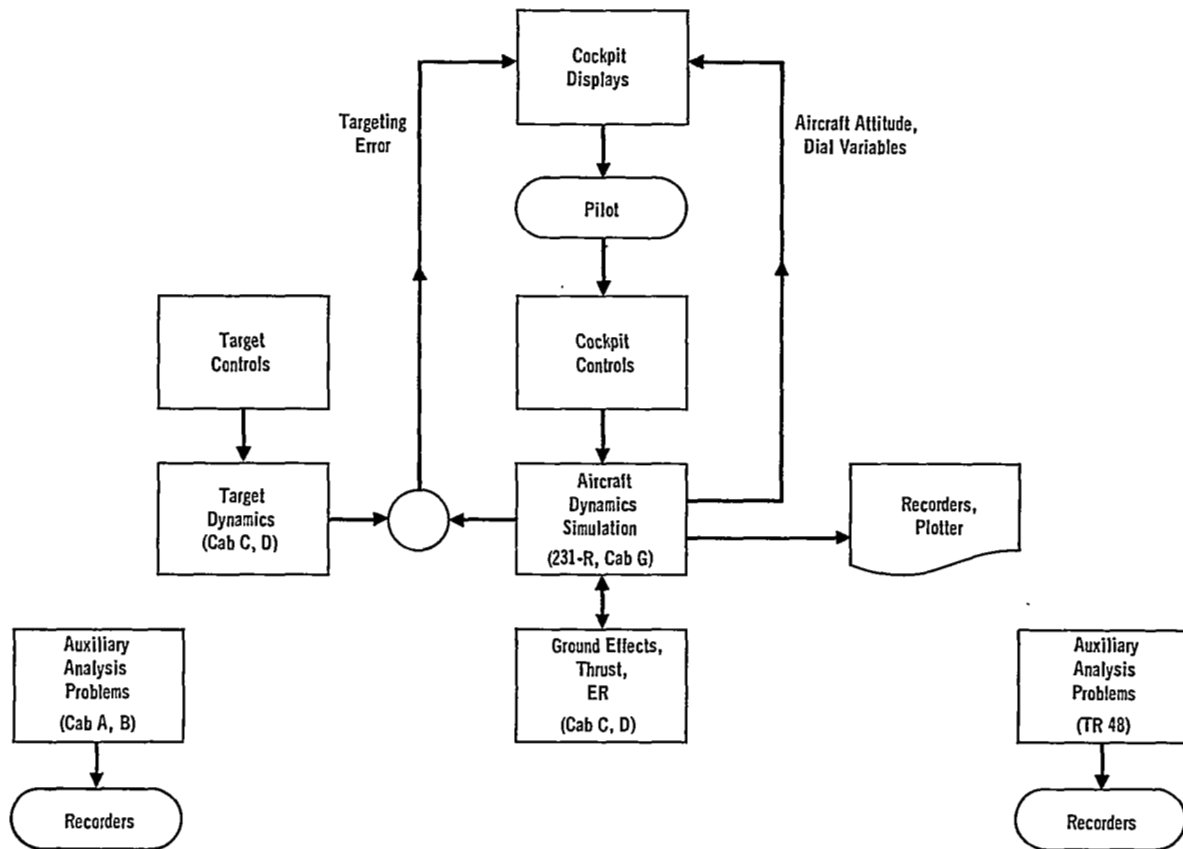
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$1200	CONSTRUCTION YEAR: 1957-59 COST \$200,000 ESTIMATED REPLACEMENT VALUE \$600,000
CONTRACTOR: Internally Constructed	LOCATION: Farmingdale, N. Y.
IMPROVEMENTS AND COSTS: (1962) Computer Expansion, Cost \$200,000; (1965) Crew Station, Cost \$50,000.	

PLANS FOR FACILITY IMPROVEMENTS: Hybridize computer with 16-bit digital component. Install full circle horizon display.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



GENERAL DYNAMICS ELECTRONIC WARFARE COCKPIT SIMULATION LABORATORY

REPORTING INSTALLATION: General Dynamics Corporation, Convair Aerospace Division P.O. Box 748, Fort Worth, Texas 76101	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Systems Technology, Dept. 062
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Aerosystems Laboratories, Dept. 062-4 L. E. Heizer Phone: (817) 732-4811, ext 4110

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The simulation laboratories are composed of three fixed base cockpits (one two-place and two single-place) and a Hybrid Computing Laboratory.

The facility is capable of operating two total equation hybrid simulations and several analog simulations simultaneously.

The three cockpits are titled (1) Electronic Warfare Cockpit, (2) F-111 Flight Control Simulator and (3) General Purpose Cockpit. The Electronic Warfare Cockpit is a single-place crew station with standard flight instruments and controls. The control system is a variable force mechanical system that can be adjusted according to the force required, mechanical throw, breakout force, etc. Special displays such as Radar, Heads-Up, Radar Warning, etc., are provided as required by program type. The F-111 Flight Control Simulator is a two-place cockpit with F-111 primary and secondary controls. The flight control system is a mock-up of the F-111 Control System, including linkages and hydraulic components. The General-Purpose Cockpit is a single-place crew station with standard flight instrumentation and a variable feel hydraulic control system.

HYBRID COMPUTING LABORATORY:

Digital - The Hybrid Computing Laboratory has a hybrid system consisting of a CDC 6600 digital computer mated with two fully expanded EAI 8800 analog computers. The CDC computer has a 65K core memory with 64 analog-to-digital and 32 digital-to-analog channels. In addition, this system has peripheral equipment consisting of three disk storage drive units, one drum storage unit, one data channel converter, one line printer, one card punch, one card reader, two magnetic tape transports and four remote display consoles.

The Hybrid Computing Laboratory has a second hybrid system consisting of an EAI 640 digital computer with an 8K core memory and a 32 A/D, 16 D/A converter system. The EAI 640 is interfaced with a PDS 1020 computer which is used for data formatting and outputting.

Analog - In addition to the hybrid capability, the laboratory has a series of EAI 231R-V analog computer consoles with a total capability of 2700 operational amplifiers, 2250 co-efficient potentiometers, and more than 100 non-linear elements that are available to provide multi-degree-of-freedom airframe simulation.

SPECIAL SIMULATION HARDWARE:

Graphics - The computer Graphics Display consists of an ITT Graphics system driven by a Honeywell DDP 516 Digital Computer. The DDP 516 has an 8K core memory and a 35 A/D, D/A converter system. The Graphics Display has both a vector generator subsystem and a character generator subsystem. All alphanumerics plus special characteristics are generated by the strobe method. The graphics display is capable of driving two separate cockpit displays simultaneously.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$3,000.00	CONSTRUCTION YEAR: 1969 COST \$ 323,405.00 ESTIMATED REPLACEMENT VALUE \$ 500,000.00
CONSTRUCTION: Internally Constructed	LOCATION: Fort Worth, Texas
IMPROVEMENTS AND COSTS: (1970) Electronic data converter addition, Cost \$10,000.00	

PLANS FOR FACILITY IMPROVEMENTS:

SPECIAL SIMULATION HARDWARE (CONTINUED)

Target Simulation - A 945-line black-and-white television system is used to project a target aircraft image on a 20 degrees by 30 degrees field-of-view screen. The target aircraft is a scale model encapsulated in a clear plastic sphere. For aspect angles the sphere is rotated by a drive system of four drive wheels on orthogonal axis. A zoom lens on the television camera gives the correct range simulation.

ELECTRONIC WARFARE COCKPIT SIMULATOR: The Electronic Warfare Cockpit Simulator provides the pilot with a representation of six-degree-of-freedom simulated motion plus a variety of CRT displays according to program requirements. This cockpit has a 20 degree by 30-degree-look-angle visual scene to provide the pilot with motion cues and visual target information. This cockpit may be used in conjunction with the General-Purpose Cockpit to simulate air-to-air intercept maneuvers. It is equipped with a mechanical flight control system having adjustments to simulate any control system feel parameters, including break-out force, total force, control system travel and trim system authority.

The Electronic Warfare Cockpit Simulator interface system includes a direct digital link from the Honeywell DDP 516 computer to the CDC 6600 computer. Solutions for the equation of motion, euler angles, flight control system and the target aircraft geometry are done by the CDC 6600 and information is transferred to the cockpit through the DDP 516. The Honeywell computer also receives information via the link to generate cockpit displays through the computer graphics system and to drive the visual display system. The Electronic Warfare Cockpit can also be interfaced to the EAI 640 Digital Computer through an Analog interface link.

TESTING CAPABILITIES: The Electronic Warfare Cockpit interfaced with the various computing facilities provides the user with an evaluation tool for several different types of programs. These programs include air-to-air weapon delivery, penetration aids system development, handling qualities and tactical maneuver development.

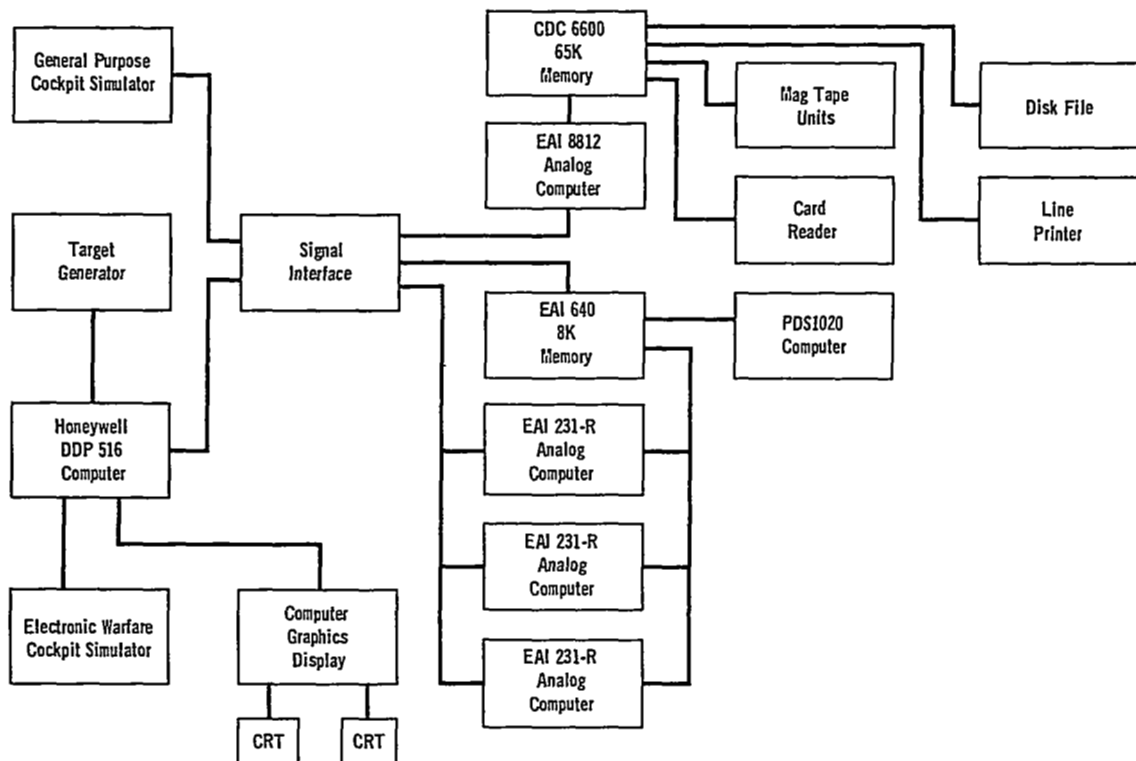
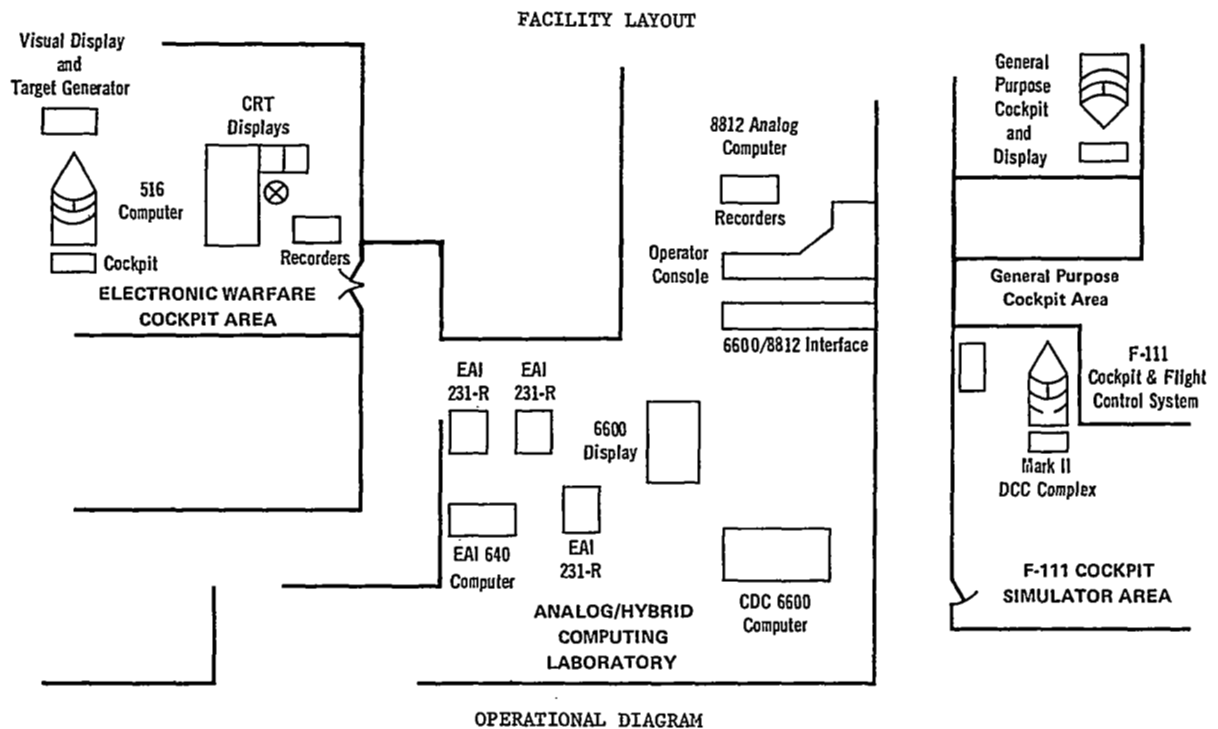
F-111 COCKPIT SIMULATOR: The F-111 Cockpit Simulator is a two-place crew station mocked up in the form of an F-111 cockpit. All primary and secondary flight controls used by the F-111 aircraft are simulated through the use of actual mechanical linkages and hydraulic components. The F-111 cockpit is interfaced to the EAI 8812/CDC 6600 Hybrid Computer through the signal interface link.

TESTING CAPABILITIES: The F-111 cockpit is used to evaluate aircraft handling qualities, establish control system design parameters and evaluate dynamic wing and tail loads during maneuvers.

GENERAL PURPOSE COCKPIT SIMULATOR: The General Purpose Cockpit is a single-place cockpit equipped with standard flight instrumentation and a general purpose hydraulic feel system for the primary controls. The General Purpose Cockpit can be equipped with a variety of different radar display and control systems and is normally interfaced with the EAI 640 computer for use in airborne intercept problems.

The EAI 640 Digital Computer and its associated EAI 231-R analog computers solve the translational equations of motion, Target-Interceptor geometry and steering equations, missile equations and scoring model.

TESTING CAPABILITIES: This facility provides the user a means to evaluate both attack systems and penetration aids systems.



GENERAL DYNAMICS SIMULATION LABORATORY

REPORTING INSTALLATION: General Dynamics Corporation Convair Aerospace Division P.O. Box 1128 San Diego, California 92112	STATUS OF FACILITY: Active
OTHER SOURCES OF INFORMATION:	COGNIZANT ORGANIZATIONAL COMPONENT: Engineering Department 500 LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation Laboratory R. D. Horwitz, Group 585 Phone: (714) 277-8900, ext 1987

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Simulation Laboratory was designed primarily for spacecraft simulations. However, as the business picture changed the cockpits and visual equipment were modified for a wide range of aircraft simulations. It basically consists, today, of a hybrid computer, a visual out-of-the-window set of television studios, data acquisition and reduction capabilities and three cockpits. Most instruments and controls are active.

The facility is arranged so that several problems can be run during one shift and that a simple problem can be dealt with as well as a very extensive problem using the CDC 6400, the XDS 930, the analog and visual equipment and the cockpit.

HYBRID COMPUTER COMPLEX: The Convair Hybrid Computer Complex consists of three analog computer consoles, a digital computer, and interconnection for communication and control. Each analog computer console and the digital computer can be programmed and operated independently of the remainder of the complex. Each of the three analog computer consoles may be interconnected with the other or with the digital computer.

Digital - There are two digital computers, the XDS 930 with 16K of core and the CDC 6400 with 132K of core. Both of these machines are nicely expanded with peripherals. The units are capable of being programmed in Fortran. Software also is provided for common analog computer control routines, such as pot setting, mode control, etc., as well as static and dynamic problem-check routines. Associated input and output equipment includes a typewriter, paper-tape reader and punch, two magnetic tape systems, and card reader. Output also is available on the Stromberg Carlson SC-4020 High-Speed Printer or 640 lpm lister.

Analog - Three CI 5000 analog consoles are available. Each COMCOR CI 5000 analog computer console is an intermediate size, general-purpose unit. For programming, each console has shielded, removable patchboards for patching all analog signals, and an unshielded removable logic patchboard. This logic patchboard contains all control interconnections for selecting operating modes of amplifiers, multipliers, and diode function generators. Terminations also are provided for a complement of digital logic elements (flip-flops, counters, etc.). Most of the programmable equipment on the analog consoles (pots, DFGs, FB limiters, etc.) can be set from either a portable keyboard, a typewriter, a paper tape reader (available at the analog console), or by instructions from the digital computer. Analog integrator modes may be controlled by relay switching for low-drift requirements, or by solid-state switching for repetitive operation or digitally controlled applications.

Graphics - Two CDC 1700's are available, one at a remote location in downtown San Diego. Both have digigraphic controls and consoles.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$720	CONSTRUCTION YEAR: 1965-66 COST \$3,000,000* ESTIMATED REPLACEMENT VALUE \$3,000,000
CONTRACTOR: Internally Constructed IMPROVEMENTS AND COSTS:	LOCATION: San Diego, California

*Estimated Value includes Computers

PLANS FOR FACILITY IMPROVEMENTS: Add moving base feel stick, projection viewing, and electronic cockpit instruments.

ANALOG COMPUTERS (CONTINUED)

Converters - For hybrid applications, an intracommunication system is provided at the analog-digital interface. This system includes 30 channels of analog-to-digital conversion and 30 channels of digital-to-analog conversion. These channels may be allocated among the analog consoles by patching at an intracom signal patch panel, or by address selection on a removable intracom logic patchboard. This patchboard also can provide information to the digital computer concerning the state of logic elements (comparators, flip-flops, counters, switches, etc.) on the analog consoles. This allows the digital computer to make decisions based on the state of these elements.

SPECIAL SIMULATION HARDWARE:

Visual Display Hardware - There are two 900 line TV studios for terrain and model pictorials giving 6 degrees of freedom. The TV has keying generators and special studios for visual inserts.

Data Reduction Hardware - Associated with the TV studios is a data station used primarily for human factors and bio-medical monitoring.

Trunking - Radiating from the Hybrid Lab are trunk lines to almost all of the test laboratories in the plant. This includes high vacuum chambers, "iron horses", the centrifuge and the human factors area.

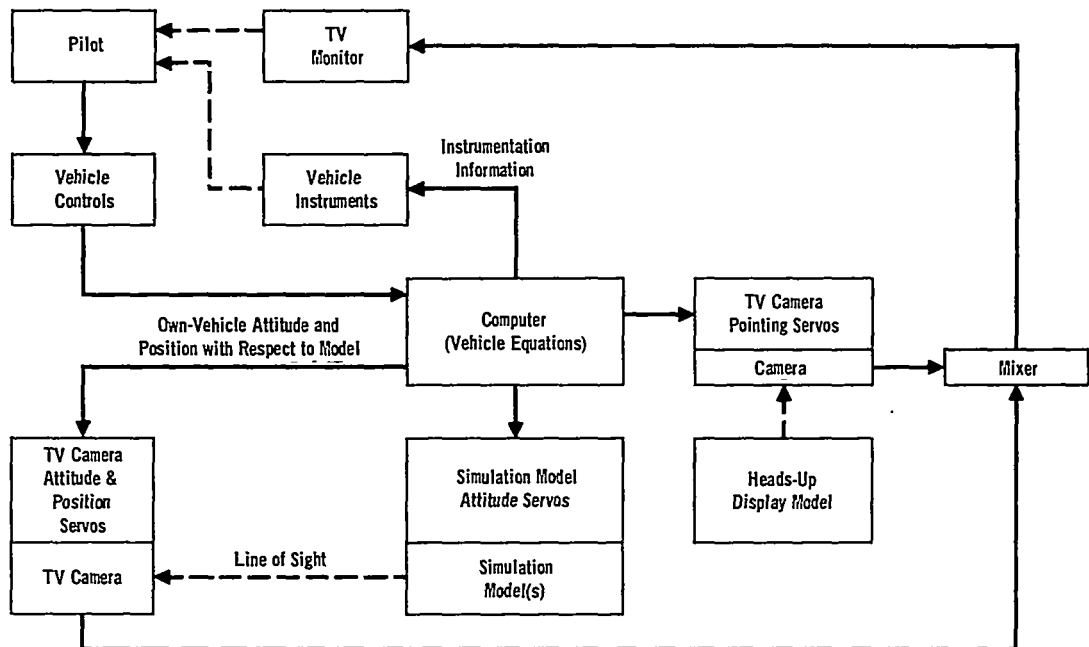
INTEGRATED MANNED SYSTEMS SIMULATOR (IMSS): The IMSS is a design and research tool for manned aircraft and aerospace systems. It consists of a fixed base-type flight deck configuration and a large kit of modular computer-compatible instruments and displays. For flexibility of control and operation, general-purpose computers control the simulator. The IMSS is hard-wired to the analog computer laboratory with its COMCOR-SDS hybrid computer and, through buffering equipment located in the analog computer laboratory, with a DMI 620 computer.

TESTING CAPABILITIES: The prime function of the simulator is to provide the designer with a tool to make his hardware as perfect, effective, or functional as possible; and when it involves man, to help the designer determine how best to divide onboard tasks between man and machine. It serves to evaluate alternative display and control configurations and alternative onboard procedures, and to evaluate man's capability for performing his assigned tasks in different missions under routine and emergency conditions. It provides evidence on which to determine which configurations are best, which of these involve the least stress and the least fatigue, what procedures are optimum, and what general rules can be derived to guide designers.

FACILITY LAYOUT

Not Available

OPERATIONAL DIAGRAM



GRUMMAN SYSTEMS SIMULATION LABORATORY

REPORTING INSTALLATION: Grumman Aerospace Corporation Bethpage, New York 11714	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Systems Technology, Dept. 692 Plant No. 05, Bethpage, N.Y.
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Systems Simulation, Group 506 N. C. Sauchy Phone: (516) LR5-6146

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Systems Simulation Laboratory occupies 13,300 square feet of floor area. It provides a high bay area for its various fixed and moving base simulators and includes a flight hardware test area, a navigation and guidance equipment integration area, an image generating system area, and a visual display and control area. Signal conditioning, interfacing and computing equipment is provided within the laboratory. A separate utility building houses power generators, dc rectifiers, hydraulic pumps and pilot air compressor equipment.

COMPUTER EQUIPMENT:

Digital - IBM 7094-II and IBM 1800 systems provide the required digital computing support to the laboratory.

Converters - Analog-to-digital and digital-to-analog conversions are provided by an Adage 770 computer link.

Analog - Three REAC 500 systems provide the required analog computing for the facility.

SPECIAL SIMULATION EQUIPMENT AND ACCESSORIES:

Flight Attitude Table Systems (FATS) Power-Tronic, Model 391 - This is a three-axis servo gimbal system with positional travels of $\pm 540^\circ$, $\pm 85^\circ$, and $\pm 540^\circ$.

General-Purpose Mobile Amplifier, Grumman-Built - These units provide 20 operational amplifiers capable of ± 100 volts dc output at 20 milliamperes. There are two units available.

General Purpose Mobile Data Logger, Grumman-Built - The unit is a two-wire 100-channel signal monitoring and decimal code print out system. The 100 channels may be automatically scanned and printed out at a rate of 3-1/2 channels per second, or each channel may be manually selected.

General Purpose Precision Voltage Reference - Reeves power supply model PS500-1. The power supply unit is used for analog voltage reference and for scale factor controls. There are four units available.

Multiple Channel Data Acquisition System, Ess Gee - The unit will handle 70 analog input channels at 100 samples per channel per second. Each channel is digitized to 13 bits plus sign. The data is recorded on digital magnetic tape in IBM 7094 format.

Strip Chart Recorders, Brush - Two 8-channel and two 2-channel recorders are available.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: COST \$ Not ESTIMATED REPLACEMENT VALUE \$ Available
CONTRACTOR: Internally Constructed	LOCATION: Bethpage, New York
IMPROVEMENTS AND COSTS:	
Not Available	

PLANS FOR FACILITY IMPROVEMENTS: Expand moving base man rated performance; add real world visual display capability for both fixed and moving base simulators. (Aircraft and Space.)

SPECIAL SIMULATION EQUIPMENT AND ACCESSORIES (CONTINUED)

Servo-Driven Flight Instruments - Rate of climb, airspeed indicator, two-axis gyro attitude indicator, altimeter, and accelerometer. An assorted list of instrument panel meters, round and edgewise, with blank scales is available.

FULL MISSION ENGINEERING SIMULATOR: The Lunar Module (LM) Full Mission Engineering Simulator is a real-time combined analog-digital manned simulator which provides a means for verifying the actual LM flight article capabilities, utilizing an integrated subsystem approach. In brief, the simulated mission profile consists of descent from a lunar orbit to the surface, ascent to rendezvous and docking with the orbiting Command Service Module; plus the ability to perform mission aborts. The complete dynamics of the vehicle is simulated with six degrees of rigid body freedom, with provision for fuel sloshing dynamics. Its major components are a fully instrumented LM cabin, visual displays, and image generators; an IBM 7094-II, an IBM 1800, three REAC 500 computers, and an ADAGE 770 data link; an experiment monitor console; and a flight attitude table.

The two-man crew station is a fixed base device mounted on a rigid platform, oriented so that each window is provided with a virtual image presentation device. The visual images are produced in another part of the laboratory and televised to the crew station on 21-inch TV monitors, which project the images through a lens system to beam splitters. The images are reflected by the beam splitters into five-foot-diameter parabolic mirrors, and then reflected into the LM cabin windows. The TV system is capable of scanning rates from 525 lines to 1075 lines. The capabilities of the system, depending upon the scanning rate selected and the light intensities used, cover a range from 600-line to 1000-line resolution. The present system uses 945 scan lines and transmits three separate video images: the lunar terrain, a starfield and the Command Service Module, which are electronically integrated by a TV special effects generator. The lunar terrain scenes are generated from scale maps of a simulated lunar surface. Both flat and curved surfaces, at scale ratios of 1,280,000:1, 96,000:1, and 800:1, are viewed during the mission. In addition to simulations at different distances from the moon, the surfaces exhibit varying shadow angles simulating angle of approach and time of day. Stars are produced by a starfield generator; a gimbaled sphere with ball bearings impressed on its surface. The starfield is floodlighted for viewing by a separate vidicon camera, while the scale model of the Command Service Module is viewed by a second, separate camera. The integrated video signal is produced as an output of the vidicon cameras mounted behind a scanoptic head. The scanoptic head provides three degrees of motion and a field of view approximating that seen by the astronaut. Six degrees of freedom of the scanoptic head is made possible by an extensible boom carried on the gimbals of a modified radar pedestal; gimbal drive command signals are given by the simulation computer. All scenes are integrated by a keying signal received from a boom-mounted camera. Close representations of the displays, switches, readouts and the attitude and thrust translation controllers are made in the crew station. An experiment monitor and problem control console provides: computer mode control, a slow-speed variable scan and readout system, problem status gates, intercom control, tape input and record system, and malfunction insertion panels. Substantial capability for on-line data monitoring and recording is provided by several eight-channel strip chart recorders for immediate readings; a high-speed scan, sample, hold and digital conversion system for recording variables on magnetic tape for processing on the digital computer; and two plotters for plotting vehicle trajectories. The LM non-motion-sensitive hardware used in the simulator tests is racked in equipment bays using cable lengths similar to those installed in the LM vehicle. Motion-sensitive hardware is mounted on the flight attitude table that is driven by computer signals representing the LM angular motion.

THREE-DEGREE-OF-FREEDOM MOTION SIMULATOR: In the motion simulator hydraulic servos position a cockpit mock-up from three direction points: two points move differentially for roll; a third point moves for pitch; while all three move simultaneously for vertical motion. Any combination of pitch, roll and heave within the mechanical limitations is thus obtained. Power for the hydraulic servos driving the platform is supplied by a pump and accumulator system capable of an average 40-horsepower output. The three servo drives employ piston-type, rotary hydraulic motors producing 17-horsepower continuously and 38-horsepower intermittently, driving the platform through 15:1 gear reduced cable-pulley systems. Electrohydraulic valves of extremely rapid response convert electrical signal command inputs into hydraulic fluid flow. Platform position information is obtained from potentiometers geared to the cable drive drums.

MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft) Velocity (ft/sec) Acceleration (ft/sec ²)	None	± 3 7 avg., 12 peak 96.6*	None
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg) Velocity (deg/sec) Acceleration (deg/sec ²)	Unknown 275 2292**	Unknown 275 2292**	None

*Based on 1000-lb total load

**Based on inertia of 60 slug-feet²

Closed-loop frequency response in vertical motion is down 3 dB at 4 hertz. Open loop, the system follows signal frequencies well past 10 hertz. Because power requirements of this device were dictated by vertical performance requirements, angular accelerations and velocities far surpass the normal requirements of any vehicle likely to be studied.

TWO-DEGREE-OF-FREEDOM SIMULATOR: The simulator consists of a simulated terrain, a projected television display, and a moving base two-man crew station. Crew station motion is provided by an endless belt having three-dimensional sculptured terrain. Wheels riding on the belt follow the changes in topography and transform signals proportional to wheel excursion and, through analog computers, control actuators capable of heaving and rolling the crew station.

The terrain is simulated by a continuous belt, 5 feet wide and 22 feet long, representing a roadbed 125 feet wide and 550 feet long. The belt runs over two 9-inch drums driven by a thyatron-controlled servo motor at simulated speeds from 0 to 6 mph. A remote-controlled image orthicon camera, capable of working at a relatively low light level, is used to televise the simulated terrain. The camera is pedestal-mounted and rotates on an axis passing through the center of the lens system. A wide angle lens provides a 60-degree optical field of view. Speed of travel is governed by a sine-cosine potentiometer attached to the yaw servo motor which also controls the speed of the belt. The lunar surface is a typical terrain simulated by bonding polyurethane to the belt. This dark gray material was chosen because it is flexible, and the color and texture approximate the moon's albedo and reflection characteristics. The foam is sculptured to depict craters ranging from 2 feet high to 2 feet deep, and 5 to 20 feet in diameter, as well as portions of much larger plateaus and craters. The ratio of the rough areas to the relatively smooth areas approximates those on lunar photographs. Additional obstacles of varying size, geometry, and special character may be temporarily attached to the belt.

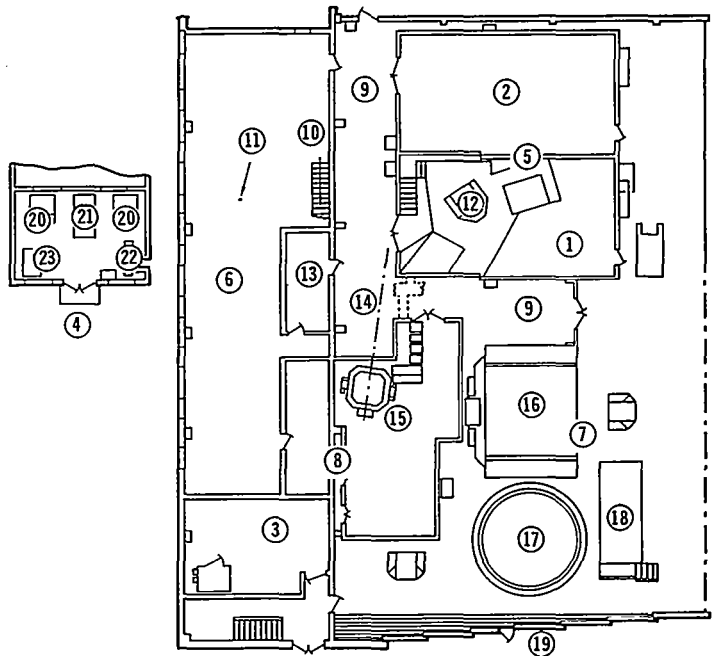
The projected incidence angles of the sun's rays on the simulated lunar surface are produced by 1000-watt projection lamps grouped to illuminate from five directions: front and back, overhead, 45 degrees, and 10 degrees. For night driving, headlights are attached to the orthicon camera to simulate high and low beams. A 525-line Waltham projector is used to project a picture of the simulated terrain on a rear projection screen placed about five feet in front of the crew station. The box-shape two-man crew station is servo driven to provide heave and roll sensations to the driver. The platform measures six feet high by eight feet wide and five feet deep, and includes a mock-up seat, instrument panel and controls, and observation window representing the Lunar Mobile Base Vehicle. Wheels attached to the camera pedestal provide sensing signals of the lunar terrain height and are converted into signal inputs to the analog computer. The computer simulates the spring-mass characteristics of the vehicle and transmits the dynamic response commands to the motion system which is driven by two electrohydraulic actuators capable of heaving the crew station three feet and rolling it ± 25 degrees.

ONE-SIXTH GRAVITY SIMULATOR: In another part of the laboratory, a one-sixth gravity simulator is used to evaluate different metalastic wheel configurations for lunar roving vehicles. To test the wheel's capability for operation under lunar gravity conditions, an inclined moving road and a three-module train were constructed. The road is canted at 80.4 degrees and the vehicles are ballasted to provide a valid simulation of lunar gravity acting upon the vehicle in the pitch plane. Velocity-sensitive hydraulic couplings joining the modules cause them to react to sharp bumps as a unit mass and to respond individually to gradual undulations. Road speed can be varied up to 10 mph, with various bump heights and distributions. Data gathered with the simulator are used to supplement analog and digital computer programs.

TESTING CAPABILITIES: Simulation programs conducted are those which are applicable to aerospace, surface, and underwater transportation, and life science studies. Entire systems are evaluated in the laboratory and the ability of the crew to operate and control the system in a realistic mission situation is verified. Crew performance is evaluated in a variety of abnormal environments, such as solitude, zero gravity, acceleration, and exposure to toxic or noxious materials.

FACILITY LAYOUT

- ① Dark Room 1
- ② Dark Room 2
- ③ Dark Room 3 Light Controlled
- ④ Utility Building
- ⑤ Visual Display & Control
- ⑥ Flight Hardware Test Area
- ⑦ Image Generation System
- ⑧ Navigation & Guidance Equipment Integration
- ⑨ Hall
- ⑩ Up-to Interfacing Room
- ⑪ Gravity 32.16030 ft/sec²
- ⑫ Crew Station
- ⑬ Office
- ⑭ North-South Line
- ⑮ Flight Attitude Table System
- ⑯ Lunar Model - Flat Surface
- ⑰ Lunar Model - Curved Surface
- ⑱ Image Generator Control Van
- ⑲ Hangar Doors
- ⑳ 400 Cycle Generator
- ㉑ Compressor
- ㉒ Switches
- ㉓ 28 Volt Rectifiers



OPERATIONAL DIAGRAM

Not Available

HUGHES MAN-MACHINE SIMULATION SYSTEM LABORATORY

REPORTING INSTALLATION: Hughes Aircraft Company Centinela and Teale Sts., Culver City, California 90230	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Display Systems and Human Factors Department
OTHER SOURCES OF INFORMATION	LOCAL OFFICE TO CONTACT FOR INFORMATION:

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The man-machine system simulation facility is a general-purpose hybrid computer system. Its main components are a Xerox Data Systems (XDS) 9300 digital computer, two Applied Dynamics, Inc., Model 4 (AD-4) analog computers, and an Electronic Associates 231-R (EAI 231-R) analog computer. In addition to the computer components, the facility has three permanent crew station simulators. These are presently configured as the F-14 Mission Control Officer's crew station simulator, an advanced avionics simulator, and a general purpose cockpit controls and displays simulator.

The facility also provides the capability for multiple sensor simulation. Briefly, this effort is directed towards multi-mode displays which can give a pilot the maximum information in an optimum manner in a minimum amount of space.

COMPUTER COMPONENT DESCRIPTION:

Digital - The digital computer is an XDS 9300 computer with 32,000, 24-bit words. Parallel digital I/O and analog conversion equipment allows communication between the digital and analog components. Another set of communication channels through an EJ30 subsystem allows direct communication with the F-14 MCO Mission Simulator. Other characteristics include a high-speed core memory, hardware floating point, a nested priority interrupt system, and a direct access to memory capability.

Peripherals include three magnetic tape units, a paper tape punch and photo reader, card reader, line printer, rapid-access drum, and parallel digital I/O and analog conversion equipment.

Analog - The analog equipment consists of two AD-4 computers and one EAI 231-R. The AD-4 provides high-performance solid state analog computing elements, patchable logic, and analog-digital conversion equipment.

The EAI 231-R analog computer provides additional analog support to the facility. It provides 160 amplifiers, 9 servo-multipliers, 12 solid state multipliers, 8 servo-resolvers and additional data trunk lines between the digital computer and the various simulators in the facility.

SYSTEM SIMULATORS:

General Purpose Cockpit Controls and Displays Simulator - This equipment provides the capability for demonstrating and evaluating air-to-ground weapon delivery from target acquisition to launch. It has the general capability to perform steering simulations, aircraft aerodynamic simulations and related studies to make this truly a general-purpose simulator. A set of flight controls with a hydraulically activated force-feel system can be tied into either of the analog computers by themselves, or in combination with the digital to provide a six-degree-of-freedom aerodynamic simulation. Other features include a television monitor, missile controls, and a heads-up display with a refractive optic collimating system in conjunction with a nine-inch exit pupil providing an external field of view to the pilot.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8 HOUR SHIFT): \$1,000	CONSTRUCTION YEAR: COST \$ Not Available ESTIMATED REPLACEMENT VALUE \$ Not Available
CONTRACTOR: Internally Constructed	LOCATION: Culver City, California
IMPROVEMENTS AND COSTS:	

PLANS FOR FACILITY IMPROVEMENTS:

SYSTEM SIMULATORS (CONTINUED)

F-14 MCO Mission Simulator - This simulator contains the controls and displays of the F-14 MCO crew station. It is used to evaluate operator performance in acquiring targets under many different simulated conditions. An integral part of this simulator is a software-oriented symbol generator which drives the stroke-written displays inside the simulator.

Advanced Avionics Simulator - This simulator is designed to demonstrate the feasibility of advanced tactical aircraft systems. The simulator is a full-scale cockpit in which operating displays and control panels are installed. The cockpit interfaces with a symbol generator, a digital scan converter, and the hybrid computing facility.

The three operating displays in the cockpit are (1) a multi-mode radar display (MMD), (2) a tactical electronic warfare display (TEWS), and (3) a head-up display (HUD).

The symbol generator for this simulator has a 1000 x 24-bit word memory which can be accessed manually via its own control panel or by communication channel tied in with the XDS 9300.

MULTIPLE SENSOR GENERATION FACILITY: The components which comprise this facility are flying spot scanners, balanced modulations, function generators, oscillators, IF strips, video amplifiers, timing devices, recorders, and operational amplifiers. These various components are used in combinations to evaluate multi-sensor displays which can operate in many different modes. This kind of evaluation involves simulation of radar, IR, laser and television sensors. Some of the techniques that have been examined are forward-looking IR, forward-looking and side-looking radar, terrain following radar, low-light-level TV, and laser scanner. These techniques have been evaluated in context with a full simulation of the operator's control and display elements.

Applied Dynamic, Inc.
AD-4 Analog Computers (2)

Xerox Data Systems
9300 Digital Computer (1)

Electronic Associates Inc.
231-R Analog Computer (1)

Multi-Sensor
Simulation

Assembly Area

Tracking Studies

Input/Output Conversion
and Interface Equipment
F-14 MCO Mission
Simulator

Integrated Avionics
Simulator

General Purpose
Cockpit Simulator

Assembly Area

The diagram illustrates the AD-4 Remote Interface system architecture, showing the flow of data and control signals between various components. Solid lines represent existing units, while dashed lines indicate expansion capability.

Input/Output and Control Section:

- Interrupts:** 32 Interrupts feed into an **Interrupt Arming** block, which connects to **Nested Priority Interrupts (256 Max)**.
- Analog I/O:** **Analog In** feeds into a **32 Channel Multiplexer**, which connects to an **A/D Conv 14 Bit** block. **Analog Out** is handled by an **8 D/A Conv (18 Bit Max)**.
- Subsystems:** The **EJ 30 Subsystem** handles **Sense Line**, **Parallel Input**, **Parallel Output**, and **Pulse Lines**. It interfaces with the **8 D/A Conv** and the **32 Channel Multiplexer**.
- Computers:** The system includes an **AD-4 Analog Computer**, an **AD-4 Hybrid Interface and Control System**, and an **EAI 231-R Analog Computer**.

Data Flow and Storage Section:

- Main Frame:** The **XDS 9300 Main Frame Floating Point Hardware** is the central processing unit. It receives data from the **Interrupt Arming** block and the **AD-4 Remote Interface**.
- Memory:** The system features **16K Memory Programmed Memory Lockout Feature Multiple Access to Memory** and a **16K Memory Multiple Access to Memory**.
- Data Paths:**
 - First Path to Memory:** Connects the **XDS 9300 Main Frame** to the **16K Memory Programmed Memory**.
 - Second Path to Memory:** Connects the **16K Memory Programmed Memory** to the **16K Memory**.
- Access and Multiplexing:**
 - The **16K Memory Programmed Memory** connects to a **Direct Access Communication Channel**, which leads to an **Access Drum 2 M Char**.
 - The **16K Memory** connects to a **Data Multiplex Channel**.
 - The **Data Multiplex Channel** branches into **Data Sub-Channel** (multiple) and an **Additional Data Sub-Channel**.

Peripheral and Interface Section:

- Time Multiplexer-Communication Channel:** Receives data from various input devices (Off-Line Plotter, 300 Increment/Sec Drum Plotter, 10 Typewriters, 8 Level Paper Tape Reader and Punch, 400 CPM Card Reader, 1000 LPM Line Printer) and feeds into the **XDS 9300 Main Frame**.
- AD-4 Remote Interface:** Acts as a bridge between the **XDS 9300 Main Frame** and the **AD-4 Hybrid Interface and Control System**. It also connects to a **Special AD-4 Data Sub-Channel for Data Chaining**.
- Special High Speed Data Path to AD-4:** Connects the **Special AD-4 Data Sub-Channel** to the **AD-4 Hybrid Interface and Control System**.
- Magnetic Tape Controller:** Manages **Magnetic Tape Transport** units.

Legend:

- Solid Line:** Existing Units
- Dashed Line:** Expansion Capability

LOCKHEED CREW SYSTEMS SIMULATION LABORATORY

REPORTING INSTALLATION: Lockheed Aircraft Corporation Lockheed Missiles and Space Co. P.O. Box 504 Sunnyvale, California 94088	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Human Factors Engineering and Simulation, 0/62-41
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Crew Systems Simulation, 0/62-41 R. L. Martindale Phone: (408) 742-4608

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Crew System Simulation Laboratory is housed in a 6000 square foot area which includes supporting shop areas, and provides for efficient operation and support of the simulation equipment. The facility includes a Simulation Computer System, a Visual Simulator, a Solar Illumination Simulator, an Integrated Display Simulator, and control/display components for configuring crew work stations, all of which are of the fixed base type. Signal distribution is through overhead cable trays. A high bay area is provided to accommodate crew stations at the Visual Simulator window optics.

SIMULATION COMPUTER SYSTEM: The computer system consists of digital computers, specialized digital processing equipment, and equipment for interfacing with the simulation hardware. The computers are an SEL 810A with 8K core and a Varian 620i with 8K core. An additional 8K core is shared by both computers for fast access bulk storage. Peripheral devices include two teletypewriters, two tape units, two high speed punch tape readers and two high speed tape punches.

Specially developed equipment interfaces the simulation hardware signals with the computers providing 296 channels of analog-to-digital at two levels with a total available sampling rate of 40,000 samples per second, 62 channels of digital-to-analog, 512 channels of discrete out with selectable levels and 350 channels of discrete in. Other signal conditioning capabilities include digital-to-synchro, signal attenuation for analog-to-digital, signal amplification at two levels for digital-to-analog and binary code - digital conversion. A digital preprocessor provides for application of three program-selectable data compression algorithms for analog-to-digital, program selection of analog-to-digital sampling rates and program control of signal interface patching.

TESTING CAPABILITIES: The Crew Systems Simulation Laboratory can simulate man/machine interfaces in complex systems. This capability is integrated into a single facility location under a single management. The laboratory provides simulations in (1) Manual control of space, undersea and surface vehicles with system dynamics, crew station controls and displays, and visual simulation interfacing with the human controller; (2) Complex integrated display presentations for manual vehicle control, sensor data processing, and situation display applications, and (3) Visibility simulations in manned space-vehicle environments.

FACILITY COST HISTORY

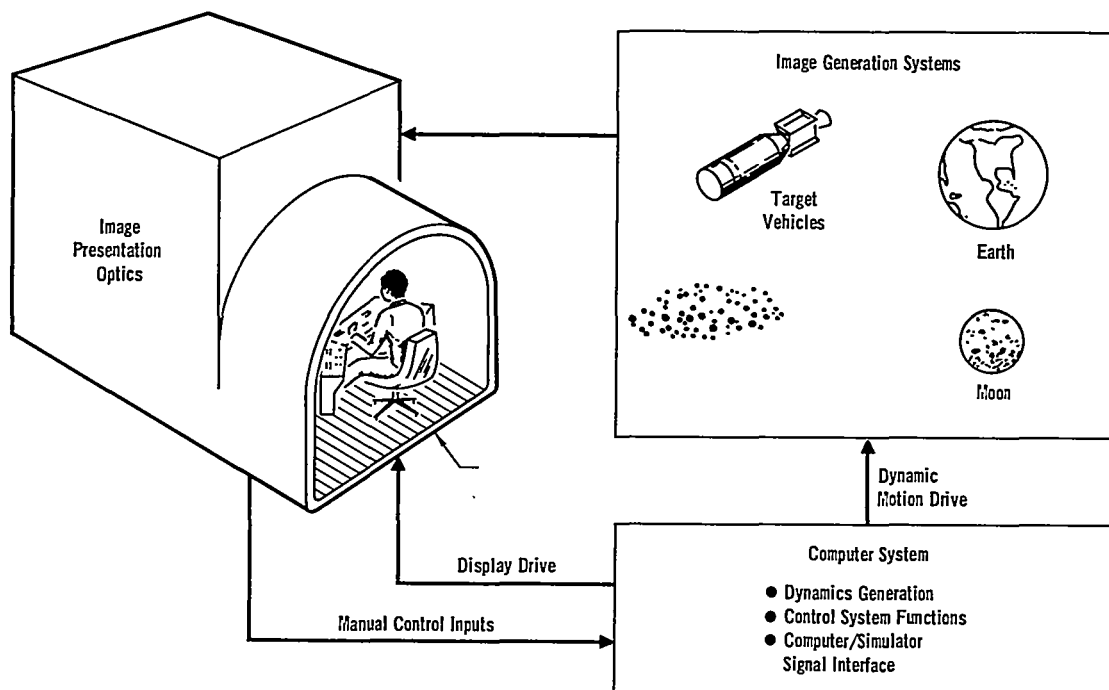
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1966-1968 COST \$ 650,000* ESTIMATED REPLACEMENT VALUE \$1,400,000
CONTRACTOR: Lockheed	LOCATION: Sunnyvale, California
IMPROVEMENTS AND COSTS: (1968-70) Simulation computer system improvements, Cost \$125,000; (1969-70) Television system improvements, Cost \$45,000; (1968-69) Illumination simulator development, Cost \$35,000; Integrated display simulator development, Cost \$120,000.	
*Does not include cost of land, building and building modifications.	
PLANS FOR FACILITY IMPROVEMENTS: Improvement of Computer/Simulator Interface Systems; Improvement of Integrated Display Simulator; Addition of Color Television for Visual Simulation.	

VISUAL SIMULATOR: Visual scene elements presented to the crew station include starfield with sun and moon, lunar surface and horizons from orbit, rendezvous and docking target vehicles, and low altitude lunar and undersea terrain. These scene elements are presented to the crew station at a 10 x 13 inch window with 90 degree field-of-view through virtual imaging optics. Images are mixed through two input channels in the optics. The starfield and rendezvous target vehicle images are directly projected into the optics. The lunar surface, docking target vehicle and terrain images are generated by models with relay into the optics via television projection. The television link is black and white with 1029 vertical scan lines and a frame rate of 30 per second. Light collimation angles from projected images are dynamically controlled to simulated range (from 16 ft to ∞). Selected motion performance characteristics are summarized in the following table:

<u>Image</u>	<u>Maximum LOS Rates</u>	<u>Threshold LOS Rates</u>	<u>Maximum Accelerations</u>
Starfield	30°/sec	1°/sec	10°/sec ²
Rendezvous Target	133°/sec	.067°/sec	83°/sec ²
Docking Target	30°/sec	1°/sec	10°/sec ²

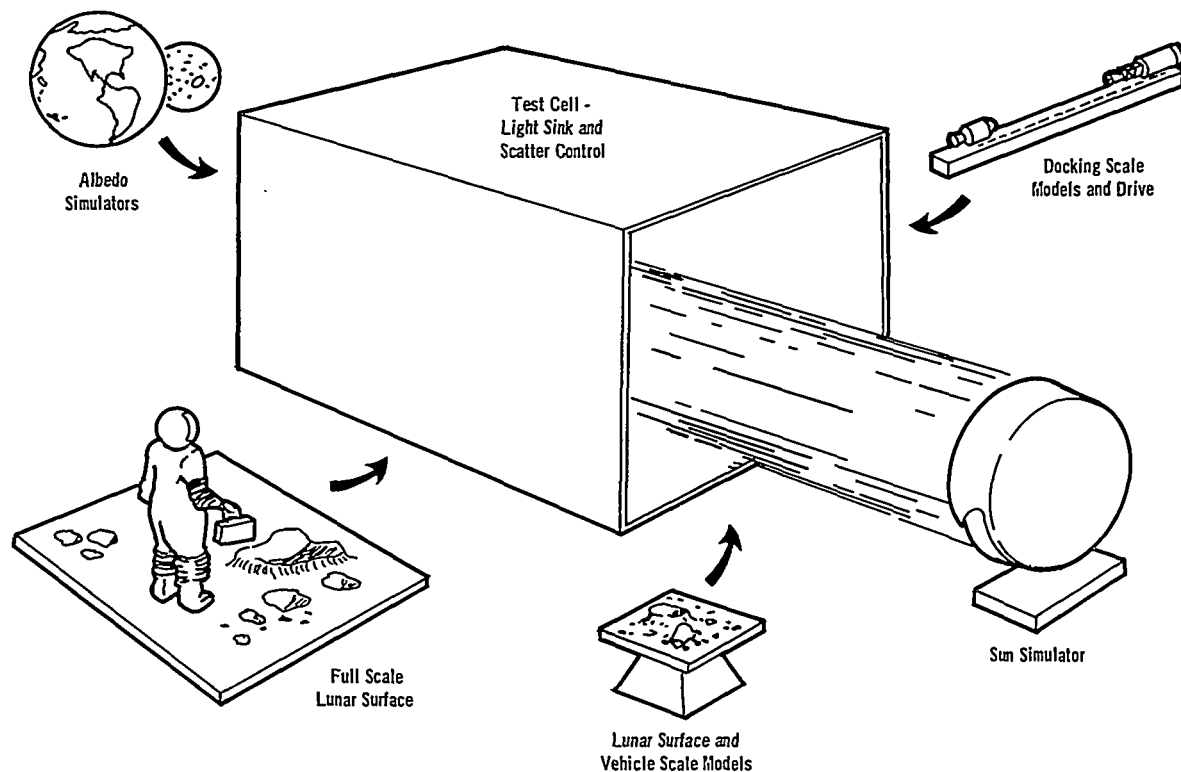
All body freedom displacements are continuous. Comparable performance is obtained from the horizon and terrain images. Lunar surface and horizon from orbit is generated from a moving rigid globe section model with conventional television probe. Terrain images use a flexible belt with probe.

OPERATIONAL DIAGRAM



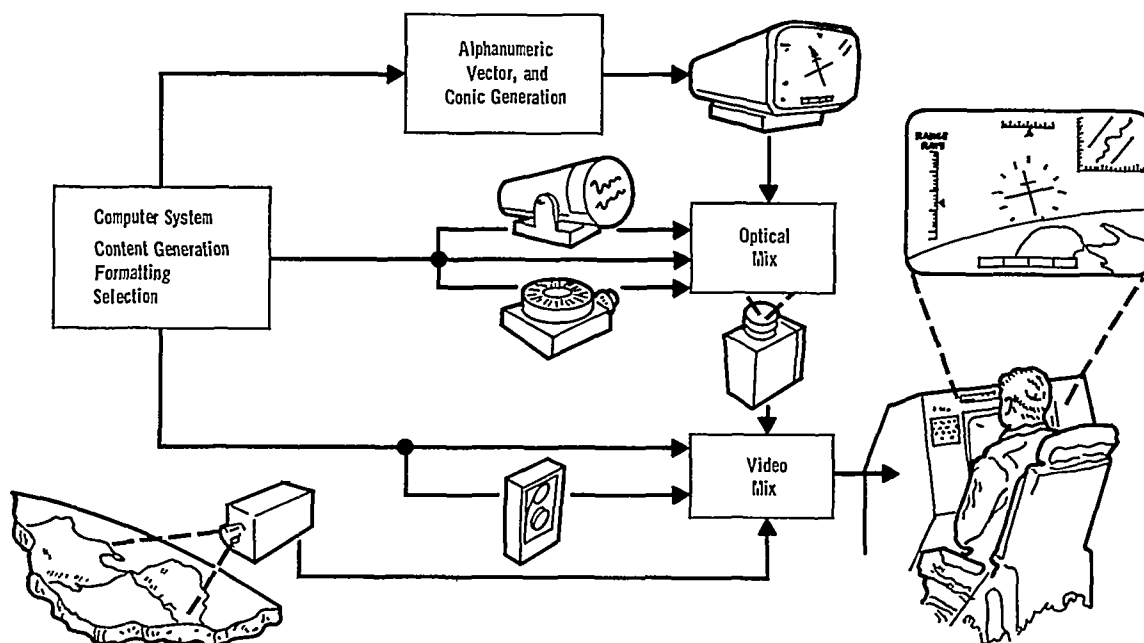
SOLAR ILLUMINATION SIMULATOR: This simulator creates space photometric conditions using physical models for purposes of evaluating visibility for conduct of crew operations. The operations include docking, EVA, surface sightings from space, lunar surface traverse, instrument reading and target vehicle detection sightings. It is also used for measuring reflectance properties of vehicle external surfacing materials and to determine camera settings for space photography. The simulator consists of a collimated (one-half degree) solar source with five foot beam diameter and correct spectral density in the visible range. This source is normally operated from .3 to .6 solar constant with the test operation scaled accordingly. Tests are conducted in a test cell which provides a radiation sink with less than one-tenth of one percent reflection back into the test area from the intercepted beam and the test objects reflections. Test objects are models placed in the beam. Extensive television, photographic and photometric measurement instrumentation is provided. Motion drives are provided for dynamic operations, such as docking, using reduced scale models.

OPERATIONAL DIAGRAM



INTEGRATED DISPLAY SIMULATOR: An integrated cathode ray tube display is presented at the crew station in raster scan format with 525 vertical lines in color or up to 1029 vertical lines in black and white. Three input channels are optically mixed to provide a composite final display output. Inputs to the optical mix include computer generated random plot alphanumeric, vectors and conics; A and B scan plots either computer or source signal generated; computer selected fixed formats from projected slides; and television imagery from recorded tapes or from the Visual Simulation System sources.

OPERATIONAL DIAGRAM



LOCKHEED FLIGHT SIMULATION LABORATORY

REPORTING INSTALLATION: Lockheed Aircraft Corporation Lockheed-Georgia Company South Cobb Drive Marietta, Georgia 30060	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Engineering Systems Test Division, 72-50
OTHER SOURCES OF INFORMATION: AIAA Paper No. 70-922, by C. P. Moore, C-5 Flight Simulation Program	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Simulation and Mechanical Systems Dept, C. P. Moore Phone: (404) 424-3451

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Lockheed-Georgia Company flight simulation laboratory is an integrated flight simulation facility equipped for real-time open-loop and closed-loop flight simulation. The available on-site and remote facility equipment includes two fixed base flight simulators of medium and large transport aircraft crew stations, analog and hybrid computers, closed circuit television visual system, terrain map, special graphics display equipment, and interface with aircraft automatic flight controls and avionics hardware. The combined facility equipment is in excess of that needed for operating two six-degree-of-freedom flight simulation problems simultaneously, one hybrid, one analog. The visual terrain scene may be interfaced with either cockpit.

REMOTE HYBRID COMPUTER COMPLEX: The hybrid computing system consists of a MAC 16 with 16K memory linked through four Astrodata Intracoms to four CI 5000 analog consoles. The CI 5000 analogs may be trunked directly to an input/output interface at the cockpit computer area for simulation access to real-time hybrid operation.

Analog Computers - The simulation laboratory analog equipment includes an SD-80 computer, an EAI (PACE) 131-R, and solid state analog computer elements for a total of 428 amplifiers, 54 multipliers, 14 function generators, 4 sin-cos generators, and 4 resolvers.

Graphics - An IDI-EI graphics system with a 21 inch CRT is available for pilot displays and other special effects displays. The graphics system is driven in real-time by any of several available computers.

VISUAL SIMULATOR: A 1029 line closed circuit color television visual simulator is used to present a realistic terrain view to the pilot. The TV camera, in effect, operates in six-degrees-of-freedom over a ground model 76,000 by 21,800 scale feet with a vertical range from 12 to 2000 feet scale altitude. The pilot's field of view is 40 degrees vertical by 50 degrees horizontal. The terrain model incorporates an instrument landing system with adjustable glide slope angle and fixed localizer for instrument approaches to a replica of the Atlanta airport. Fully controllable special effects provide for low ceiling, visibility and scud. A high altitude model can be selected for unlimited range of cruise flight.

COCKPIT SIMULATOR STATIONS: The cockpit simulators are transport aircraft flight stations with side by side pilot and copilot seating and wheel, column, and rudder pedal control. These cockpits are fitted with electrohydraulic feel systems that provide the proper static and dynamic force displacement relationship for the wheel, stick, and rudder. The systems are fully programmable to simulate the aircraft feel system elements of an aircraft flight control system. Each of the cockpits is equipped with fully operational flight instruments, status displays, primary flight controls, engine controls, and appropriate inputs to trim, flaps, landing gear, thrust reversers, and the automatic flight control system. Both cockpits have access to the closed circuit television visual simulator. The visual scene for the large transport cockpit is back projected onto a translucent screen and is viewed from the

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$1300 - \$3000 *	CONSTRUCTION YEAR: 1966 \$ 750,000 ESTIMATED REPLACEMENT VALUE \$1,500,000
CONTRACTOR: Lockheed	LOCATION: Marietta, Georgia
IMPROVEMENTS AND COSTS: (1967) Visual system and terrain map (Dalto Electronics Corp.), Cost \$350,000.	
* Depends on amount of shared hybrid computer time used.	

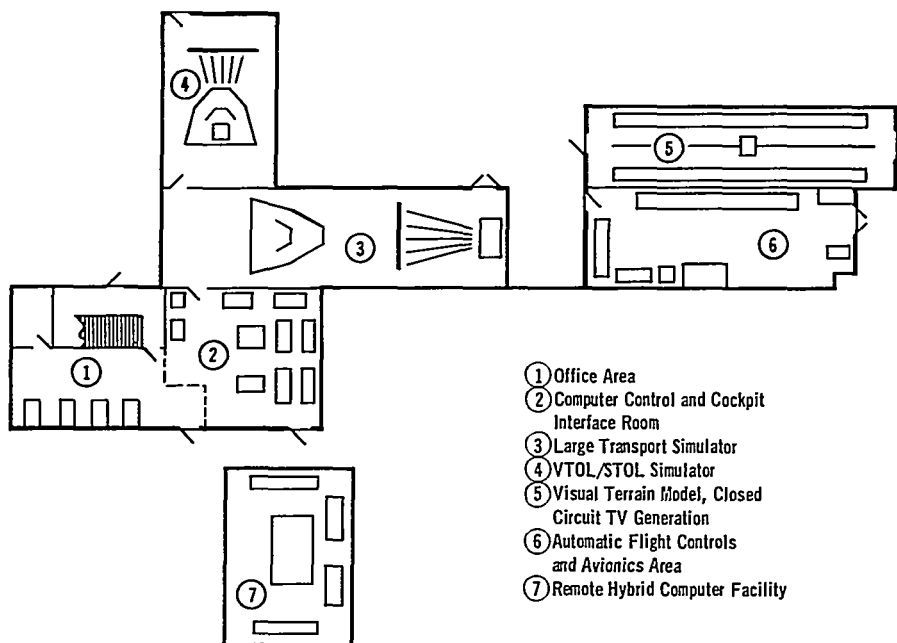
PLANS FOR FACILITY IMPROVEMENTS: Equip cockpit with 6-DOF moving base system, incorporate heads-up display with present instrument display.

COCKPIT SIMULATOR STATIONS (CONTINUED)

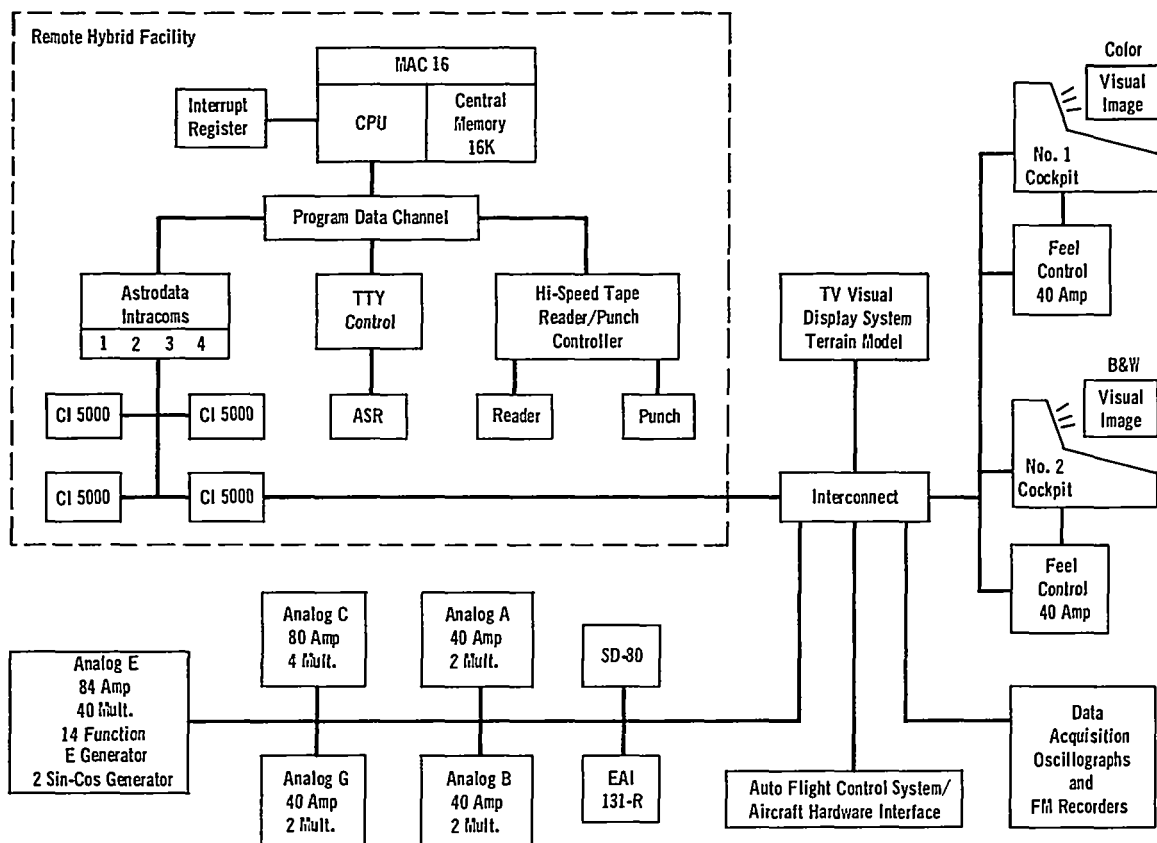
pilot's position through a virtual imaging lens. The VTOL/STOL cockpit visual presentation is a direct-viewed, front-projected system.

TESTING CAPABILITIES: This facility provides important stability and control information and establishes bases for design of flight controls and stability augmentation. Pilot tasks at cruise and high speed including turn entry and exit, changes in trim conditions, investigation of stick force/g relationships, and examinations of the phugoid and short period effects. Low speed approach and landing characteristics for ILS capture, tracking and the landing flare maneuver can also be evaluated.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



LOCKHEED FLIGHT TRAINING SIMULATOR

REPORTING INSTALLATION: Lockheed Aircraft Corporation Lockheed-California Company P.O. Box 511 Burbank, California 91503	STATUS OF FACILITY: Active
	COGNIZANT ORGANIZATIONAL COMPONENT: Flight Operations, Dept 98-37, Bldg 608, Plant 10
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Operations, J. Cooley Phone: (805) 272-2406

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Training simulator is an integral part of the overall Flight Crew Training program conducted by Flight Operations Department. Training is oriented primarily toward, but not limited to, the training of airline customer pilots of Lockheed L-1011 aircraft.

COMPUTER COMPLEX: The computer complex consists of two XDS SIGMA II digital computers and one Honeywell Satellite, 96K Memory, 8 I/O Channels, 2 magnetic tape units, 3 teletypes, a card reader, a paper tape reader and punch, a Sanders display unit and 2, 3-Megabyte disk file.

MOTION SYSTEM: The six degrees of freedom motion system simulates the motion cues received by the flight crew in flight and on the ground.

The following maximum excursion, velocities and accelerations can be achieved by the system.

AXIS	EXCURSION	VELOCITY	ACCELERATION
PITCH	+30° -25°	± 20°/sec	± 30°/sec ²
ROLL	± 20°	± 16°/sec	± 20°/sec ²
YAW	± 25°	± 20°/sec	± 20°/sec ²
VERTICAL	± 2.8 feet	± feet/sec	± 24 feet/sec ²
LATERAL	± 4.9 feet	± 2.6 feet/sec	± 16 feet/sec ²
LONGITUDINAL	± 4.2 feet	± 2 feet/sec	± 16 feet/sec ²

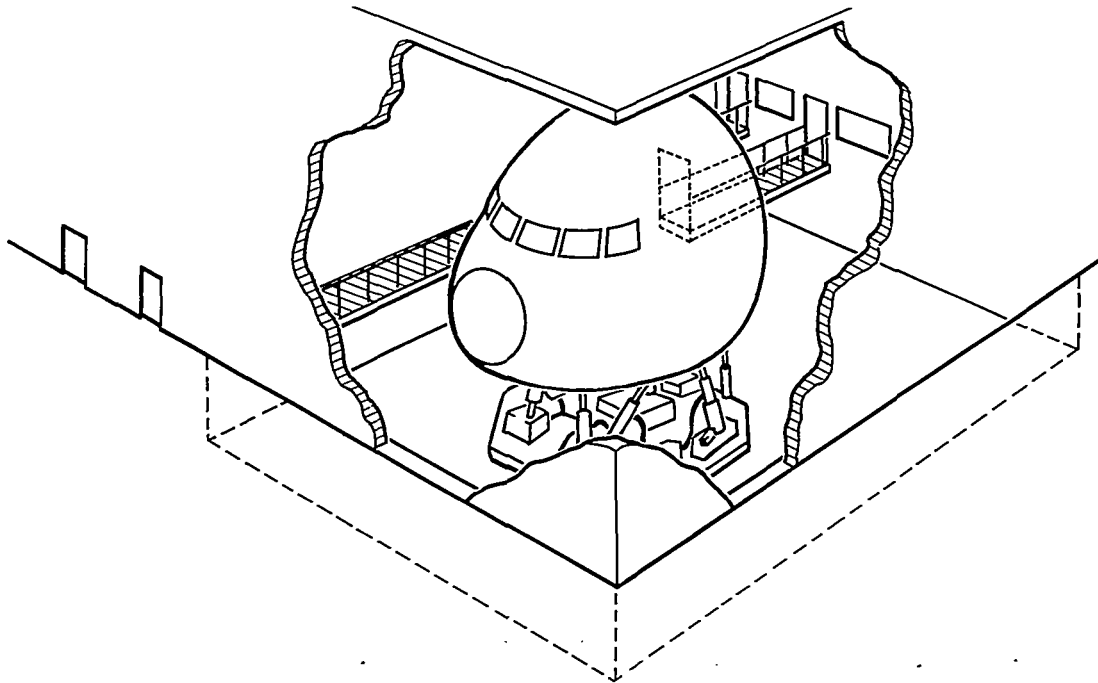
VISUAL SYSTEM: The VAMP (variable anamorphic motion picture) visual system is a film projection display system designed for flight simulators to provide visual scene simulation. In operation the VAMP system enables synthetic changes to be produced in the apparent viewing position of a motion picture taken from an aircraft flying a prescribed mission. This synthetic change is produced by means of optical elements which alter the perspective of the projected image.

FACILITY COST HISTORY

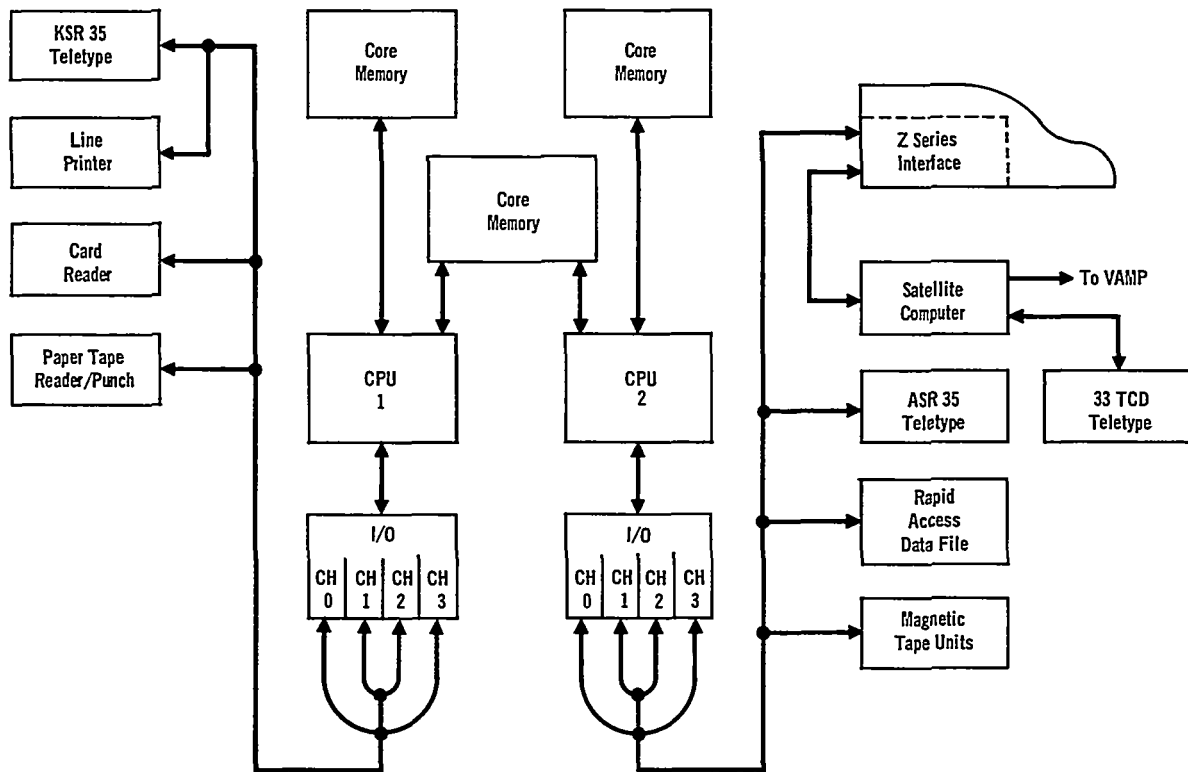
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1969 COST \$ 121,000.00 ESTIMATED REPLACEMENT VALUE \$ Not Available
CONTRACTOR: William Simpson Construction Company IMPROVEMENTS AND COSTS: Not Available.	LOCATION: Los Angeles, California

PLANS FOR FACILITY IMPROVEMENTS: NOTE: New facility, unable to give further information at this time.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



LTV FLIGHT SIMULATION FACILITIES

REPORTING INSTALLATION: LTV Aerospace Corporation Vought Aeronautics Company P.O. Box 5907 Dallas, Texas 75222	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Flight Technology
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Simulation, Unit 2-53350 Mr. P. C. Dillenschneider Phone: (214) 266-4529

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The simulation laboratory is made up of four specific areas occupying approximately 25,000 ft² of floor space. These are (1) a real time hybrid computing facility occupying approximately 8000 ft², (2) a fixed base simulation area of approximately 5000 ft², located adjacent to the computing facility, (3) a small-amplitude moving base facility of approximately 2500 ft², located on an adjacent floor, and (4) a new facility location of approximately 10,000 ft², located remotely (approximately 500 feet) from the computer area which will house the new large amplitude moving base and the new general purpose visual system. This new addition will be occupied in the first quarter of 1971.

The various simulation hardware devices and computing equipment are employed as building blocks to provide a simulation capability in support of specific program needs. Several typical configurations are identified below.

HYBRID COMPUTING FACILITY: The hybrid computer facility houses four high speed, general purpose digital computers, six analog/digital linkage systems and six Electronic Associates Inc., analog consoles. Each digital computer has the I/O equipment necessary for independent operation. The Xerox Data Systems (XDS) computers have the additional capability of communicating with any other XDS computer in the system. These intercom systems provide an easily expanded multi-processor hybrid complex. The following is a list of these digital computers:

- a. Two XDS 930 computers with 12K and 20K of memory.
- b. Two XDS SIGMA 5 computers with 24K of common memory each with independent CPU operation.

Interface with the various simulator stations is provided through digital-to-analog converters, digital-to-synchro converters, and discrete lines.

SPECIAL SIMULATION HARDWARE:

Simulator Cockpits - Several cockpits are available:

- a. Conventional flight controls and computer driven instrument displays are provided in two, fixed base, single-place fighter type cockpits with the internal dimensions of the F-8 aircraft. Mechanical systems provide control feel with a stick shaker used as an indication of penetration into the simulated aircraft buffet boundary. An inflatable "G" suit, under computer control, provides the pilot with normal (Nz) acceleration cues. Both cockpits are currently in use in a two-man, two-aircraft air-to-air combat simulation.
- b. One single-place general purpose F-8 cockpit with moving base capability is available. The cockpit includes the normal, conventional flight controls and a collective stick, for either

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$400-4,000*	CONSTRUCTION YEAR: 1970 COST \$2,400,000 ESTIMATED REPLACEMENT VALUE \$3,000,000
CONTRACTOR: Internally Constructed	LOCATION: Dallas, Texas
IMPROVEMENTS AND COSTS: (1971) Large amplitude motion system performance tests, man rating and cockpit, Cost \$155,000; (1971) General purpose visual system modeling, lighting and installation, Cost \$55,000; (1971 Miscellaneous facility improvements, Cost \$55,000.	

PLANS FOR FACILITY IMPROVEMENTS: Continued general development of visual system, sound, crew stations, and control feel systems.

SPECIAL SIMULATION HARDWARE (CONTINUED)

conventional or V/STOL simulation purposes. Variable, mechanical control feel systems are incorporated in all axes with provisions for a force servo system in the longitudinal axis. The adjustable feel forces encompass those found in the XC-142A, the F-8 and A-7 aircraft. An extensive array of computer driven cockpit instruments is provided. This cockpit is currently in use, installed on a small amplitude moving base, in a night carrier landing approach study.

- c. One single-place simulated A-7D/E cockpit is configured for moving or fixed base simulation programs. The cockpit, control feel, instrument display and weapons delivery functions of the A-7D/E are faithfully reproduced. The cockpit is currently in use, fixed base, in an A-7D/E Tactical Mission simulation program. The actual airborne Head-Up Display and weapon delivery and navigation computer are incorporated in the simulation loop.
- d. One single-place, fixed-base simulation A-7 aircraft cockpit, currently being used for laboratory investigations of control feel systems is provided with the normal flight controls, instrument provisions and A-7 control feel characteristics.
- e. One two-place, fixed base, simulator cockpit having the internal dimensions and control functions of the XC-142A V/STOL aircraft is available for future simulation activities.

Visual Displays - Current visual displays rely upon computer generated image information stored in a rapid access, fixed-head magnetic storage disc or alternatively in the main computer memory bank of an XDS 930 digital computer. The information is processed through a special purpose display computer driving an end display in a beam writing mode or vector stroke fashion. Three different end displays are now in use. The first of these is a Schmidt projector providing an image on a curved screen through a folded optical path. The image is viewed through a collimating lens system providing the pilot with approximately an 80 degree conical field of view. Three such systems are available. The second end display is a 19-inch shadow mask color CRT faced with a direct viewing collimating lens system providing the pilot of a simulator cockpit with a 20° x 30° field of view. The scene in the latter case is in color. Two such systems are in use. The third end display utilizes refractive optics to project an image on the interior of a spherical screen. Two such systems are employed for air combat simulation.

A new general purpose visual system is presently being installed to provide a visual scene for a variety of flight simulation tasks. This system incorporates proven techniques and equipment of the latest design to capitalize on accumulated field experience. The system consists of a high resolution black and white television camera (1029 lines) in combination with a special optical lens system, all mechanized to simulate the motion of a pilot's eyepoint over a scaled terrain model. The lens system on the camera contains optical elements which are motor driven under computer control to follow the three-axis rotational motions of the simulated aircraft. The camera itself is mounted on a carriage, which is also computer driven through motors to provide the three linear motions of the simulated aircraft. The unscaled maximum linear movements are 50 feet by 15 feet by 12 feet, while rotational movements are unlimited (special techniques required in pitch). The terrain model being overflown is presently a mosaic composed of aerial photographs scaled to provide the desired flyspace. Other models with different scale factors and flyspace, may be substituted to suit specific simulated missions. The camera views a relatively restricted portion of the forward field of view, generally along the boresight of the simulated aircraft (approximately 38° x 48° field of view). The resultant television signal may be used to drive a variety of visual end-display attachments on fixed or moving base simulator cockpits.

Motion System - A three angular degree of freedom (plus one redundant degree) small amplitude moving base, originally developed for astronautic simulation, is currently in use on aircraft flight simulation programs. Since the cockpit is mounted on a moment arm in the pitch and yaw axes, motions about these axes also produce heave and lateral acceleration, respectively. Maximum performance capabilities are identified below.

SPECIAL SIMULATION HARDWARE (CONTINUED)

SMALL AMPLITUDE MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical (from pitch)	Lateral (from yaw)
Displacement (ft) Velocity (ft/sec) Acceleration (ft/sec ²)	None	± 1 5.4 +176,-112	± 1 5.4 ± 144
Rotary Motion	Roll	Pitch	Yaw
Displacement (ft) Velocity (ft/sec) Acceleration (ft/sec ²)	± 20 90 11,460	± 10 52 1,318	± 10 52 1,375

The motion system is mounted inside a 20 foot diameter spherical screen enclosure facilitating direct projection techniques for visual flight cues. Interchangeable cockpits are easily coupled to the moving base.

A new large amplitude motion system is currently being fabricated and will be placed in operation during mid 1971.

The motion system is a five degrees of freedom configuration (vertical, lateral, roll, yaw and pitch) that is driven by hydraulically powered linear actuators. The moving base system is composed of a beam structure approximately 24 feet in length that is pivoted about two axes at one end with a three-axis angular gimbal-cockpit support system mounted on the opposite end. Beam motion provides the vertical and lateral motion, while the angular gimbal system provides the pitch, roll and yaw motion. Maximum performance capabilities of the new motion system are defined below.

LARGE AMPLITUDE MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft) Velocity (ft/sec) Acceleration (ft/sec ²)	None	± 10 ± 20 $\pm 62.4^*$	± 5 ± 10 ± 19.3
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg) Velocity (deg/sec) Acceleration (deg/sec ²)	± 15 ± 30 ± 343	± 10 ± 18 ± 58	± 10 ± 16 ± 116

*From $lg = 32.2 \text{ ft/sec}^2$; Frequency response: 0 to 3 Hz with less than 30° phase shift.

AIR COMBAT SIMULATOR: The air combat simulator was developed for evaluation of aircraft and aircraft armament systems in close-in visual air combat environments. The simulator consists of two manned fixed base cockpits, interconnected through "out-of-the-window" visual displays. Each pilot is free to maneuver his simulated aircraft anywhere within its flight envelope, in real time, in response to the dynamic combat situation as he sees it develop. An encounter is terminated with expenditure of munitions by either participant or after a fixed time interval. The "winner" of an engagement is determined by post-flight evaluation of the resultant records on the basis of selected weapon conversion criteria. Simulator generated parametric results of aircraft or armament system tradeoffs may be used in conjunction with more conventional methods to arrive at the most cost-effective configuration.

Each pilot occupies a fixed base single-place fighter aircraft type cockpit installed inside a spherical screen enclosure. The conventional control arrangement includes stick, rudder pedals, modulated afterburner throttle, speed brakes, trigger, and variable wing sweep. Single gradient mechanical feel systems provide control feel about all three control axes. Parallel "beep" trim is incorporated in the longitudinal system. Cockpit instrumentation includes the altimeter, airspeed/Mach number, rate of climb,

AIR COMBAT SIMULATOR (CONTINUED)

three-axis attitude indicator, normal acceleration, wing sweep position, and fuel quantity. A longitudinal stick shaker simulates penetration into aircraft buffet, increasing in magnitude to an uncontrollable stall departure. Stall recovery is accomplished by relaxing stick pressure. The pilot normally wears a "G" suit which is inflated to provide suitable normal acceleration cues and a representative pilot work load.

The visual display provides the pilot with a near 3 π steradian field of view by direct projection on the surface of a 16 foot diameter spherical projection screen surrounding each cockpit. Visual information includes the opponent aircraft image in proper location, orientation, and size; an attitude stabilized representation of the earth/horizon/sky; and gunsight imagery including two fixed reticles, a lead compensation pipper, a range scale, and an "in range" (gun) firing bracket. The aircraft image is generated and processed in a digital computer driving a fixed, high brightness, 6 inch diameter cathode ray tube (CRT) in a light pencil fashion. The computer-generated aircraft image is focused on the surface of the spherical projection screen by a refractive optics system and a center mounted gimbal supported mirror. Mirror rotation positions the aircraft image in proper azimuth and elevation while changes in perspective and range appear as changes in image information on the face of the CRT. The earth/horizon/sky image, providing aircraft attitude and heading information, is generated by an off-centered, gimballed, point light source projector and suitable mask. Gunsight imagery, along the aircraft waterline extension, is provided by separate projectors. Visual system resolution provides realistic target attitude information to ranges of 3 to 4 nautical miles.

CARRIER APPROACH SIMULATOR: The Carrier Approach Simulator consists of a six degree of freedom (DOF) representation of the airplane, a three DOF representation of the aircraft carrier (pitch, translation, and heave), a visual display of the night carrier landing situation, and a single-place cockpit with instruments and appropriate control functions. The cockpit is mounted on a moving base providing acceleration cues due to pilot control inputs and atmospheric turbulence. The objective of the simulation is to investigate the handling qualities of an aircraft on the carrier approach glide slope from glide slope intercept to touchdown. A means is thereby provided for the flight test pilot to participate in and influence the aircraft design to ensure carrier suitability.

The simulated cockpit is a typical single-place aircraft configuration with conventional stick and rudder primary flight controls, throttle, and speed brake control. Longitudinal parallel beep trim and proportional spring loaded to center direct lift control are provided about all three axes. Mechanically adjustable breakout and single force gradients are provided in the lateral and directional channels while a programmable electro-hydraulic force servo system provides feel forces in the longitudinal channel. Computer-driven cockpit instruments include attitude direction indicator, airspeed, altitude, rate of climb, angle-of-attack, angle-of-attack indexer, pitch trim, speed brake position, and engine rpm. A simulation of engine noise, modulated by throttle movements through a suitable lag, is provided through a headset or loudspeaker system. The visual display, consisting of a collimating lens system and a 19-inch shadow mask color cathode ray tube mounted above the instrument panel, provides a 20° by 30° view of a carrier at night. The visual image generated in the digital computer is a realistic reproduction in true color of the carrier deck edge lights, the runway center line and edge lights, the runway end lights, the vertical drop line at the ramp, and the Fresnel Lens Optical Landing System (FLOLS). The FLOLS provides the pilot with a visual glide slope during the carrier approach. A large centered red light designated the "meat-ball", rides in a vertical path with respect to a set of horizontal green datum lights. The movement of the ball from the centered position is directly proportional to glide path change from the nominal. The visible glide slope variation is $\pm 3/4^\circ$ about the nominal. A simulated real world horizon is also provided in the visual display. The visual scene responds to the pilot's control inputs, FLOLS stabilization inputs, and to carrier pitch and heave motion so as to continuously display a correct perspective view of the carrier light system down to wire engagement, wafeoff, bolter, or ramp impact. The cockpit and visual display are mounted on a three DOF moving base which provides coupled angular and linear acceleration cues in the pitch-heave and yaw-side acceleration axes as well as pure roll acceleration cues. Mechanization of the base drive equations is tailored to provide realistic motion cues based upon a pilot opinion study of control inputs during the initial test phase of the approach simulation. Moving base disturbances are also generated in response to atmospheric and carrier wake disturbances.

MISSION SIMULATOR: The Mission Simulator was conceived to evaluate the compatibility and functional capability of new avionics systems, the cockpit layout, and pilot under a simulated mission environment. The initial simulation employed extensive mathematical models of the complete avionics systems. Later developments have included the incorporation of major avionics hardware elements: the Navigation and Weapons Delivery Digital Computer, the Flight Director Computer, the Heads-Up Display and the digital computer I/O communications panel.

MISSION SIMULATOR (CONTINUED)

The mission simulator is a very extensive fixed base simulation of the A-7 airplane, flight control system, and crew station coupled to an equally extensive avionics system which is part simulated and part actual flight hardware. A simulated "out-the-window" visual display provides a VFR as well as an IFR capability to the pilot. The simulator may be "flown" over the complete flight envelope of the aircraft in a continuous fashion from takeoff, through enroute navigation, ground attack and landing, exercising in the process the airborne Navigation and Weapons Delivery Digital Computer, the Heads-Up Display and finally the Flight Direction Computer during a simulated ILS approach. The simulator cockpit is an actual A-7 aircraft nose section, reconfigured for simulation purposes and equipped with a complete array of computer driven cockpit instruments. Controls include the primary flight controls; throttle, gear and flap controls; control stick grip with its conventional disarray of switches and buttons; armament system management switches; AFCS switches; HUD controls; and the Navigation and Weapon Delivery Computer controls. Switches are provided for the selection of the numerous functions and modes of auxiliary equipment operation. Two separate proportional controls were also provided for slewing of the HUD aiming reticle - a single axis (displacement) thumb wheel on the throttle and a two axis pencil (rate) control on the left hand console.

Realistic primary flight control feel forces are provided in the lateral and directional channels by the incorporation of actual aircraft hardware while the longitudinal axis employs a force servo system to simulate the dual bobweights. The aircraft stick force sensor is also incorporated and coupled to the simulated AFCS. The airborne HUD and computer I/O panel occupy the same locations as in the aircraft. The "out-the-window" display provides the pilot with a collimated 50° field of view of an austere-stylized-ground plane, written in a light pencil on a black background. Two modes of visual operation are possible. The first - applicable to the takeoff and landing - provides a view of a runway with equally spaced tarstrips, several adjacent stick figure buildings, and a horizon line. The second mode, switch activated from the cockpit, includes the enroute and attack information which is limited to a horizon line, a straight line road, two pyramid mountains, and two widely separated stick figure ground targets. The collimated HUD symbology is superimposed on this "out-the-window" scene by the normal combining glass. Great care has been required in the mathematical modeling of the complete aircraft and avionics systems as well as the model of the real world Earth and atmosphere in order to exercise the major modes of the total avionics system. Specific mathematical models emphasized include:

- a. A complete unrestricted six DOF representation of the airframe including all major aerodynamic parameters and non-linearities.
- b. A complete simulation of the aircraft control system including the various AFCS modes.
- c. Inertial navigation system which provides the basic aircraft velocity and attitude information.
- d. Forward Looking radar which provides target range and bearing.
- e. Doppler radar which provides ground speed and drift angle.
- f. Radar altimeter which provides altitude above the target.
- g. Air data computer which provides true airspeed, Mach number, and pressure altitude.
- h. Weapons ballistics used in the release point predictions.
- i. Atmospheric and wind model.
- j. Earth representation as a rotating ellipsoid of revolution and associated gravity field.

Each mathematical model is mechanized to the extent required to achieve fidelity over the frequency range of interest. The computer mechanization is nearly all digital. It requires an SDS-930, two-thirds of the capacity of an SDS SIGMA 5 and approximately 70 analog amplifiers interfacing between the digital computer, cockpit instrumentation and analog recording. Prior to a simulated flight, the airborne computer is loaded with the current flight program by using the same programming tape as used in actual flight. Initial aircraft coordinates and as many as nine checkpoints or target locations are inserted manually. The first checkpoint or target is selected on the computer I/O panel. Following a conventional takeoff the visual scene is manually switched to the enroute mode. Steering information is provided on the HUD, the vertical pointer of the ADI and bearing pointer on the HSI. Ground track and range information is also presented on the HSI. Visual fix taking provisions are provided by overflying a known checkpoint and updating the computer on passage.

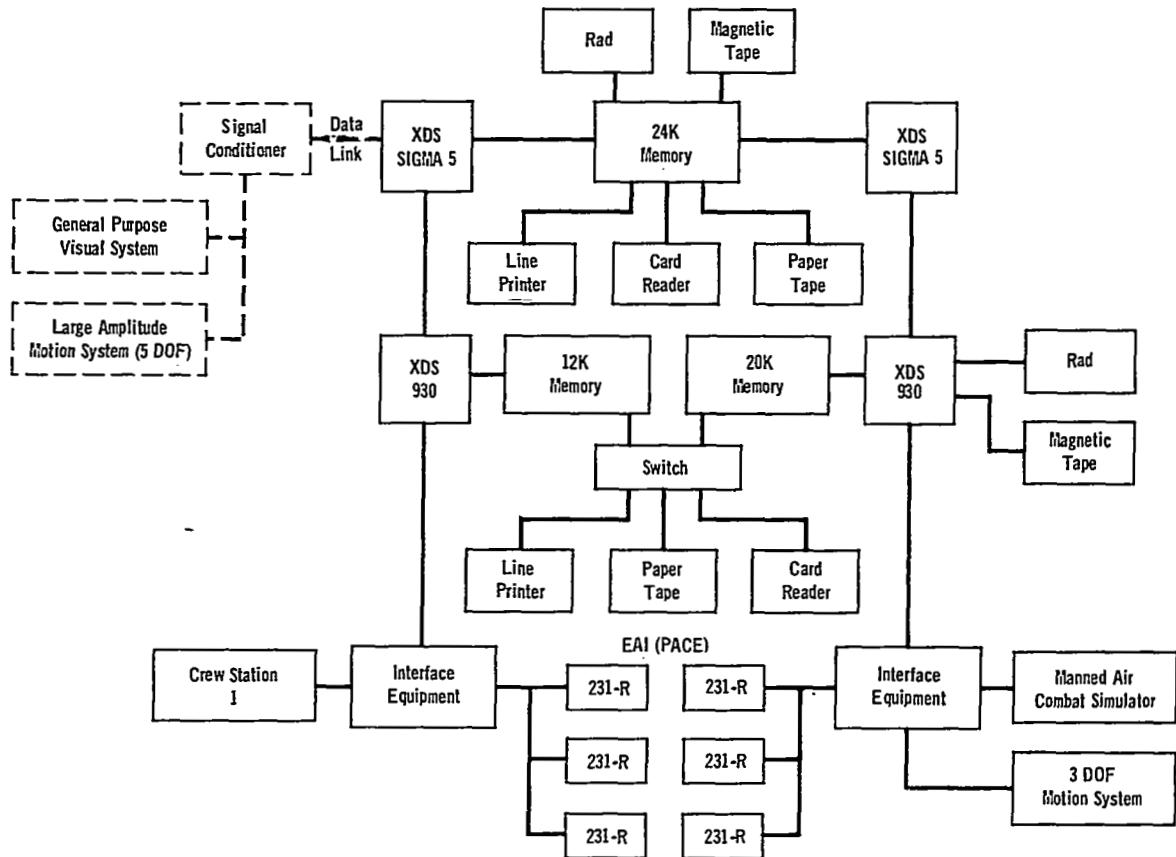
MISSION SIMULATOR (CONTINUED)

As the target is approached, the HUD display and computer solution is switched to the attack mode. The appropriate weapons management switches are selected identifying weapon type, station, and single or multiple drop. The HUD aiming reticle is positioned over the target by maneuvering the aircraft or by the two alternate HUD reticle controls. Update of the alignment of the aiming reticle with range closure is manually accomplished with either controller. Continuous aircraft azimuth steering commands are provided on the HUD. The steering command need only be satisfied at the release point, providing the pilot with evasive maneuvering capability during the attack. Normal, normal offset, and nav. bomb modes are possible including normal, toss and over the shoulder delivery. Assessment of weapon delivery accuracy is defined by a blast circle written in the visual window upon reacquisition of the target area. Selection of the enroute mode provides guidance commands to the destination. The landing mode provides HUD, HSI and ADI steering commands for an ILS approach. The visual runway scene is programmed to appear at an altitude above touchdown of 200 ft. Selection of the Flight Director Computer mode provides lead guidance signals for interception of the ILS.

FACILITY LAYOUT

Not Available

OPERATIONAL DIAGRAM



MARTIN SPACE OPERATIONS SIMULATION LABORATORY

REPORTING INSTALLATION: Martin Marietta Corporation P.O. Box 179 Denver, Colorado 80201	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Advanced Concepts Department (1640)
OTHER SOURCES OF INFORMATION: "Integrated Maneuvering and Life Support System Simulation", Final Report, Apr 1969, MCR-69-184	LOCAL OFFICE TO CONTACT FOR INFORMATION: Systems Research Department (1641) G. W. Smith Phone: (303) 794-5211, ext 2736

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Space Operations Simulator facility consists of five interdependent parts -- the moving base carriage, the control capsule, simulation instrumentation, the test monitor station, and the hybrid computational equipment.

Moving Base Carriage - The Martin Marietta moving base carriage utilizes the "powered" simulation approach rather than the "free-motion" approach. A 90 by 32 by 24 foot room, providing an 8640 cubic foot maneuvering volume, houses the moving base which is servodriven in three translational axes and three rotational axes. The base of the carriage translates the length of the room on three rails and is driven by four one-horsepower AC motors which engage two gear racks mounted on the floor. The vertical pedestal translates on rollers and rails laterally on the base structure and is driven by two one-horsepower AC servomotors. The gimballed head located on the front of the pedestal is supported by a set of negator springs and counter-balance weight. This system effectively counterbalances the weight of the gimballed head and its payload. Two one-quarter-horsepower DC motors, which engage two vertical gear racks on the front of the pedestal, provide the servo-power for the vertical translation. The gimballed head has been designed to provide maximum safety and freedom of motion for the test subject. Motors and gear drives are enclosed in the structure of the gimbals. The gimbal sequence of roll, pitch and yaw was selected because it allows all three drive axes to nominally pass through the c.g. of the test subject. Thus, counterbalance and overhanging moment problems on the gimbal axes are minimized. Each gimbal is driven by a one-quarter-horsepower DC motor. The overall weight of the moving base carriage is 5000 lb.

MOVING SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Lateral	Vertical
Displacement (ft)	60.0	± 6.0	± 6.0
Velocity (fps)	3.0	3.0	3.0
Acceleration (fps ²)	6.0	3.0	3.0
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 57.3	± 217.74	± 177.63
Velocity (deg/sec)	114.6	114.6	114.6
Acceleration (deg/sec ²)	458.4	458.4	458.4

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$2,000-4,000	CONSTRUCTION YEAR: 1961 COST \$ Not Available ESTIMATED REPLACEMENT VALUE \$ Not Available
CONTRACTOR: Internally Constructed	LOCATION: Denver, Colorado
IMPROVEMENTS AND COSTS: (1963) Facility modifications, Cost \$116,000; (1964-70) Capital equipment, Cost \$250,000	

PLANS FOR FACILITY IMPROVEMENTS: New gimballed attitude head for the moving base simulator (increased attitude motion, variable response).

FACILITY DESCRIPTION (CONTINUED)

Control Capsule - Several control capsules have been in operation in the SOS laboratory; only one, however, seems to provide adequate flexibility. This mock-up has a two-man capacity and contains sufficient display and control instruments to allow several types of space mission tests to be run. These tests include both manual and automatic piloting and ground tracking as well as aerial tracking. Normally, a flight requires the use of both the out-the-window scene and several instruments.

SOS Instrumentation - Limb Motion Sensor (LIMS) - For many of the manned simulations (EVA, IVA, Maneuvering Units, etc.) it is necessary to compute c.g. shifts and inertia changes as a function of limb position. Also, in the case of some maneuvering units (HHMU, for example) the orientation of a thrust vector relative to the test subject's torso must be known. The LIMS was designed to fill this need. By monitoring the orientation of each of the body pivot points and knowing the length of the connecting links, the dynamic effects of c.g. shifts, inertia changes, and self-induced rotations can be computed and introduced properly into the problem. Also, the orientation and location of thrust vectors for simulated handguns can be computed, using LIMS extensions.

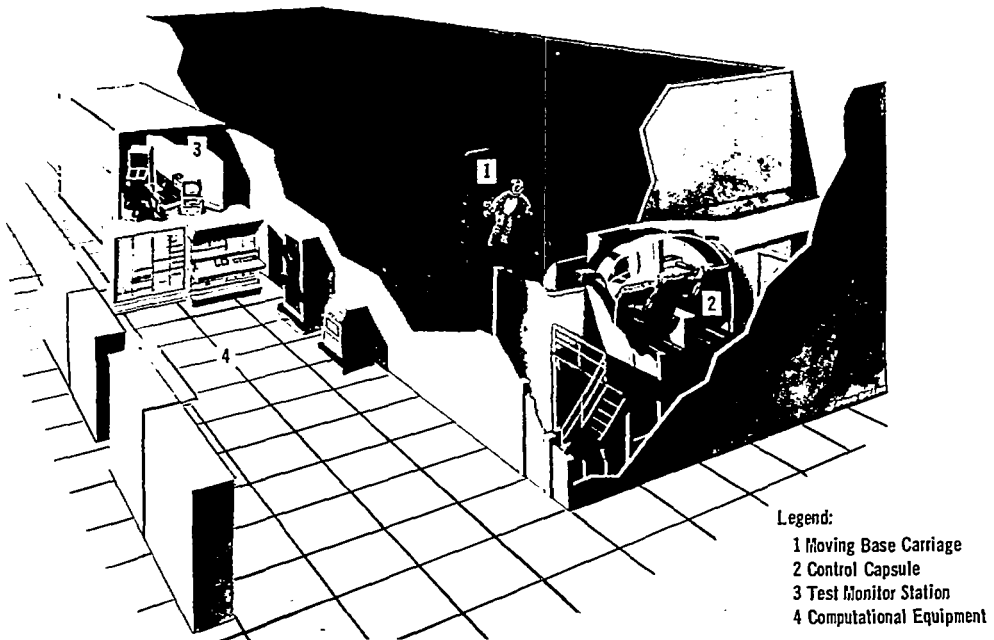
Load Cell Array - For EVA/IVA simulations where the test subject is in contact with the simulated space station, the contact forces and moments must be measured in order to be able to simulate the problem. In the SOS facility, an array of load cells is used to measure the contact conditions. The work site or vehicle mock-up is mounted on a load-sensing platform which is an equilateral triangle with two load cells at each apex. The load cells are mechanically attached to the platform with pairs of flexure points. The total configuration is symmetrical about any axis that contains the centroid and any apex of the triangle.

Test Monitor Station - Simulator operation is controlled by an engineer at the test monitor station. From the monitor panel he has control of the servo power to the moving base and the computer control signals. Also, a wide range of test points can be monitored. This monitor station provides another safety check on the proper functioning of the simulator. The engineer can override the computer and remove power from the moving base at any time.

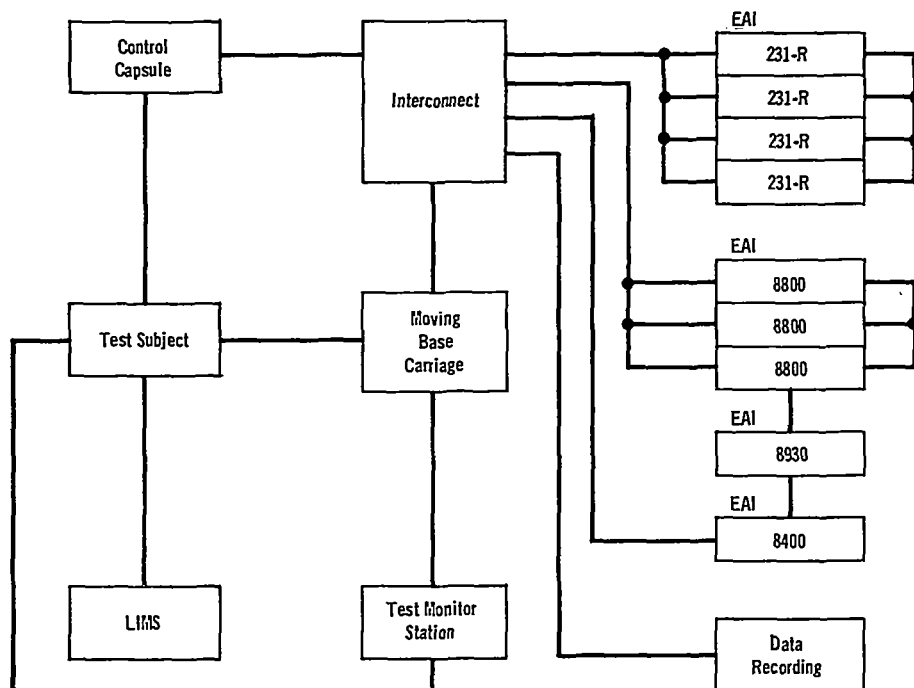
Computational Equipment - The simulator is supported by two computer systems. One system contains four EAI 231-R computers located as an integral part of the facility. The other consists of a hybrid computer installation composed of three EAI 8800 analog computers, one EAI digital computer, and one EAI 8930 linkage subsystem.

TESTING CAPABILITIES: In the area of manned space missions, the capability exists to study maneuvering units, EVA, IVA, space-to-ground tracking, space-to-space tracking, rendezvous, and docking. Also, space hardware such as optical radars and docking mechanisms can be evaluated.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



MCDONNELL-DOUGLAS FLIGHT SIMULATION LABORATORY

REPORTING INSTALLATION: McDonnell Douglas Corp., McDonnell Aircraft Co. P.O. Box 516 St. Louis, Missouri 63166	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Laboratory and Flight Division Dept 251
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Simulation, Dept 251 J. P. Capellupo Phone: (314) 232-7406

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Simulation Laboratory is a unified laboratory complex, oriented primarily toward, but not limited to, manned, real-time flight simulation. It comprises a hybrid computer complex, five crew stations, (four fixed base and one motion base), a terrain map, horizon displays, airborne target displays and associated hardware.

The facility can operate two hybrid simulations and several analog simulations (depending on problem size) simultaneously. Terrain, horizon and target displays can be routed to any of the crew stations.

The crew stations are equipped with active primary and secondary flight controls and active flight instruments. Radar, heads-up display and other special displays and controls are provided as required. Long term "g" effects are provided by "g" suits, "g" cushions and blackout simulation. A wide-spectrum noise generator is used to provide sound cues of engine rpm, afterburner, speedbrake, skin noise, flaps, landing gear, buffet, tire contact and runway rumble.

HYBRID COMPUTER COMPLEX:

Digital - The digital computer is a CDC 6600 computer with 98K memory, 10 peripheral processors, 12 I/O channels, 2 line printers, a card reader, a dual CRT console, paper tape reader and punch, 3 magnetic tape units, 6 -210 consoles and a 75,000,000-character disk file.

Graphics - The graphics system is composed of a CDC 1700 computer with 24K memory, 16 external interrupts, interrupt data channel, a fully buffered data channel, a paper tape station, magnetic disk transport, 6600- to 1700-channel coupler, 2 digigraphic controllers, a digigraphics console, and 2 peripheral tonal scopes.

Converters - Analog-digital and digital-analog conversions are provided by an ADAGE 770 and an ADAGE 784.

Analog - The 700 amplifier analog computer system is composed of 3 EAI (PACE) 231-R, 4 EAI (PACE) 131-R, an Applied Dynamics AD-4, a MILGO 4100 analog computer, and an EAI 350 digital operations system.

SPECIAL SIMULATION HARDWARE:

Terrain Map - Three dimensional (20 x 40 ft) 1000:1 scale map used for takeoff, landing and air-to-ground studies. Visual pickup is an 875-line black and white television system.

Horizon Generator - An 875-line black and white television system used to produce cloud cover horizon in the forward 60° field of view.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$7500	CONSTRUCTION YEAR: 1968-69 COST \$ 956,000 ESTIMATED REPLACEMENT VALUE \$1,917,000
CONTRACTOR: Internally Constructed	LOCATION: St. Louis, Missouri
IMPROVEMENTS AND COSTS: (1970) Air-to-air combat simulator, fixed base, Cost \$511,000; (1970) Shuttle (DEDA), fixed base, Cost \$450,000.	

PLANS FOR FACILITY IMPROVEMENTS: Expand Moving Base man-rated performance, improve air combat visual system.

HYBRID COMPUTER COMPLEX (CONTINUED)

Target Simulation - Three 875-line black and white television systems used to generate all-aspect target display.

MANNED AIR COMBAT SIMULATOR (MACS): The MACS is a real-time, fixed base, two-aircraft hybrid simulator that employs two piloted crew stations (MACS I and MACS II) with out-the-window displays. These crew stations may be linked together to provide air-to-air combat capability or used individually for air-to-ground combat studies with an unrestricted field of view and altitude variability.

The 20-foot diameter fiberglass domes house cockpits which have been configured as advanced tactical fighter aircraft. The cockpits are complete with active flight instrumentation such as a three-axis attitude direction indicator, Mach meter, airspeed indicator, angle-of-attack indicator, rate of climb meter, altimeter, and "g" meter. Other instruments and CRT display capability for radar and moving map simulations, as well as warning lights and switches, are available in the cockpits to complete a realistic simulation.

The manual controls integrated into the cockpits include a two-axis control column for longitudinal and lateral control which contains a feel system to provide realistic force response to pilot input and rudder pedals for directional control. Both the longitudinal and lateral feel systems can be manually trimmed by the operational trim switch on the control stick. A throttle quadrant and speed brake switch provide speed control.

Physiological cues have been incorporated in the crew stations to give the pilot additional flight information. These include the use of "g" cushions and "g" suits to indicate load factor, buffet simulation through high frequency square wave oscillations input to the stick servo, wide spectrum noise generators to provide sound cues, and a grayout-blackout simulation by dimming cockpit and out-the-window displays.

The high resolution Virtual Image Projection System (VIPS) used in the forward 60° field of view of the MACS I and II crew stations consists of two images (target and horizon) collimated near infinity. The VIPS uses a television monitor for the horizon and another for the target image. A two-axis (pitch and yaw) beamsplitter located in the target path is used to position the target properly with respect to the cockpit. The horizon monitor and reflected target monitor are combined on a multiplexing beamsplitter, and the resulting scene is collimated through use of a large beamsplitter and spherical mirror.

The apparent range between the target and attacker is simulated using a raster shrinkage technique. This technique electronically varies the raster image size while retaining the same number of raster lines for target representation, and yields a high resolution target at long range. The roll orientation of the two aircraft is simulated using a rotating prism. These functions are contained in an electronic raster control unit within the crew station room.

The optical system used in VIPS is not restricted to the air combat situation. It can also be used to present a high resolution image of the large-scale terrain map for use in air-to-ground weapon delivery, takeoff, and landing studies. Both land- and carrier-based simulation are available.

When the target is outside the forward 60° conical field of a MACS cockpit, the target image is projected on the interior of the dome by one of two Real Image Projections Systems (RIPS). The gimballed mirror positions the image in the correct location relative to the crew station, and a focus lens is positioned to compensate for variations in total projection distance. The real image projection systems, one on each side of the crew station, combine with the virtual image projection system to provide complete 360° cockpit visibility for MACS crew stations.

Aircraft attitude cues (horizon) are provided outside the forward 60° field of view by means of a three-axis gimballed color horizon generator mounted above and behind the pilot's head. This generator consists of a servo driven dome, a high intensity light source, and a three-axis gimbal system.

The equipment for simulation air combat includes a Control Data Corporation (CDC) 6600 digital computer system, one MILGO 4100 Analog Computer, an ADAGE 784 hybrid interface link, two separate cockpits, a CDC 1700 digigraphics display system, and visual display equipment such as cameras, aircraft models, and TV projectors. The rotational 6-degree-of-freedom equations of motion, euler angles, flight control system, thrust and drag definitions, aerodynamic model, atmospheric model, missile and gun models, scoring models, and visual display drive equations are simulated on the CDC 6600. The data flow between the CDC 6600 and the analog computers is dual and is accomplished via the hybrid interface link. The order of data flow is analog to digital with a transmission cycle of 50 milliseconds. The data flow between the CDC 6600 and CDC 1700 digital computers is singular and is accomplished via a 6600 system data channel and a 1700 system coupler. The order of data flow is 6600 to 1700 with a transmission cycle of one second.

MANNED AIR COMBAT SIMULATOR (MACS) (CONTINUED)

TESTING CAPABILITIES: This facility provides the user with a means for evaluating the manned performance of proposed weapon systems. It is used to evaluate flight controls, cockpit arrangement and displays, fighter gun and missile effectiveness, and to develop new tactics for fighter aircraft. In addition, it is used to evaluate handling qualities, establish control system design goals and to assess dynamic wing and tail loads.

VARIABLE GEOMETRY SIMULATOR (VAGES): The VAGES is a real-time, fixed base simulator that employs one piloted crew station with out-the-window displays. The principal features of VAGES are:

- o Enclosed cockpit complete with control sticks, rudder pedals, throttles, head-up display, and flight instrumentation.
- o A high resolution rear projected target and horizon in the forward 60° conical field of view.
- o A Variable Size Spot Projector, for target representation, to give line of sight, target range, bank angle, and aspect information when the opponent is not on the forward screen.
- o A 360° horizon image generator to provide aircraft attitude cues outside the forward 60° field of view.

The VAGES enclosure houses a cockpit which has been configured initially as an F-4, but has mechanical and electrical provisions to change internal geometry. These provisions allow the variation of cockpit dimensions and internal instrumentation to achieve flexibility in cockpit configuration.

VAGES uses a rear projection, translucent screen approximately 10 feet in front of the pilot, filling his forward 60° field of view. Two projection systems, located behind the screens, are used during air combat simulation to present the pilot the appropriate display. A TV projector is used to project the horizon image, while a gimbaled mirror used in conjunction with a second projector is used to superimpose the target image on the screen. The mirror is used to position the target at the correct location relative to the crew station. During air-to-ground simulation, the horizon projector is used to project an image of the terrain map.

In the VAGES, a gimbaled spot projector is used to indicate the target location relative to the crew station outside the forward 60° field of view. The size of the projected spot can be changed to indicate range to the target, with maximum and minimum diameters of nine inches and one-quarter inch, respectively. Additional spot projector cues, such as blinking and color, are used to give the pilot target attitude information during air-to-air combat simulation. Gimbal limitations prevent spot projection in the rear 60° field of view.

Aircraft attitude cues (horizon) are provided outside the forward 60° field of view by means of a gimbaled projector mounted above and behind the pilot's head.

TESTING CAPABILITIES: This facility provides the user with a means for evaluating the manned performance of proposed weapon systems. It is used to evaluate flight controls, cockpit arrangement and displays, fighter gun and missile effectiveness, and to develop new tactics for fighter aircraft. In addition, it is used to evaluate handling qualities, establish control system design goals and to assess dynamic wing and tail loads.

MOVING BASE SIMULATOR (MBS): The MBS is a real-time, large amplitude, 5-degree-of-freedom motion base simulator that employs a single-place advance fighter type cockpit with out-of-the-window displays. The MBS is a flexible design tool used for takeoff and landing, handling qualities, pilot induced oscillation, gust and turbulent loading, precision tracking, and terrain following studies. The MBS cockpit has operational controls and instruments similar to those of the fixed base manned air combat simulator. The cockpit is mounted on the end of a 20-foot movable boom which has two rotational degrees of freedom, and the cockpit has three rotational degrees of freedom with respect to the end of the boom. Boom rotation will cause the crew station to translate in the vertical and lateral directions.

Crew station motion is produced by hydraulic actuators. A 250-hp electric motor drives a 150-gpm, 3000-psi pump which is the power source for all motions. One hundred gallons of hydraulic fluid is stored in an accumulator to provide large transient acceleration requirements. The following table contains the performance specification of the Motion Base Simulator.

MOVING BASE SIMULATOR (MBS) (CONTINUED)

<u>Degrees of Freedom</u>	<u>Displacement</u>	<u>Velocity</u>	<u>Acceleration</u>
Vertical	± 10 ft	± 16 fps	+6 g, -4 g
Lateral	± 5 ft	± 8 fps	+1 g
Pitch	$\pm 30^\circ$	$\pm 170^\circ/\text{sec}$	$340^\circ/\text{sec}^2$
Roll	$\pm 45^\circ$	$\pm 300^\circ/\text{sec}$	$\pm 1000^\circ/\text{sec}^2$
Yaw	$\pm 30^\circ$	$\pm 120^\circ/\text{sec}$	$\pm 170^\circ/\text{sec}^2$

The near-term studies planned for the MBS do not require the above capability; therefore, the hydraulic pressure has been reduced to 2000 psi and the MBS is man-rated at the following performance specifications:

<u>Degrees of Freedom</u>	<u>Displacement</u>	<u>Velocity</u>	<u>Acceleration</u>
Vertical	± 10 ft	± 13.5 fps	+3 g, -1 g
Lateral	± 5 ft	± 6.5 fps	± 1.0 g
Roll	$\pm 20^\circ$	$\pm 100^\circ/\text{sec}$	$\pm 240^\circ/\text{sec}^2$
Pitch	$\pm 30^\circ$	$\pm 30^\circ/\text{sec}$	$\pm 300^\circ/\text{sec}^2$
Yaw	$\pm 30^\circ$	$\pm 30^\circ/\text{sec}$	$\pm 240^\circ/\text{sec}^2$

The MBS is housed in a room approximately 20 ft wide, 55 ft long and 35 ft high, adjacent to the hybrid computer facilities.

The visual display system employed on the MBS is a 25 inch television monitor viewed through a collimating lens. This system affords the pilot a 45° field of view. Any of the visual display generators may be "patched in" into the MBS visual system for pilot viewing.

TESTING CAPABILITIES: This facility is used for extensive tests and evaluations of advanced tactical fighter and spacecraft designs. The moving boom concept offers the structural rigidity required for simulating high performance aircraft as well as permitting unobstructed out-of-the-window vision. Evaluations made cover handling and flying qualities, flight control system, trim control system and power control systems.

SPACE SHUTTLE FIXED BASE SIMULATOR: This simulator operates in real time, and employs a two-place crew station with out-the-window displays. It is a flexible, closed-loop test bed used for the following engineering design analyses:

- o Evaluation of instruments and displays
- o Subsystem management studies
- o Human factors studies
- o Preliminary flight controls evaluation
- o Development of software requirements for onboard computer
- o Testing of vendor hardware

The pilot's station has a full complement of electromechanical and electronic displays and instruments for simulating all mission phases. The co-pilot's station contains mock displays and instruments. Active flight instrumentation includes an attitude direction indicator, a horizontal situation indicator, engine rpm and fuel gages, "g" meter, angle-of-attack indicator, rate-of-climb indicator, and altimeter. Mode switches have been provided for autopilot, stability augmentation system, and reaction control modes.

SPACE SHUTTLE FIXED BASE SIMULATOR (CONTINUED)

The manual controls integrated into the cockpit consist of a two-place, two-axis control stick (longitudinal/lateral), rudder pedals, a three-axis hand controller and a three-axis translational controller. Both the longitudinal and lateral feel systems can be manually trimmed by an operational trim switch. Throttles and speed brakes are provided for velocity control.

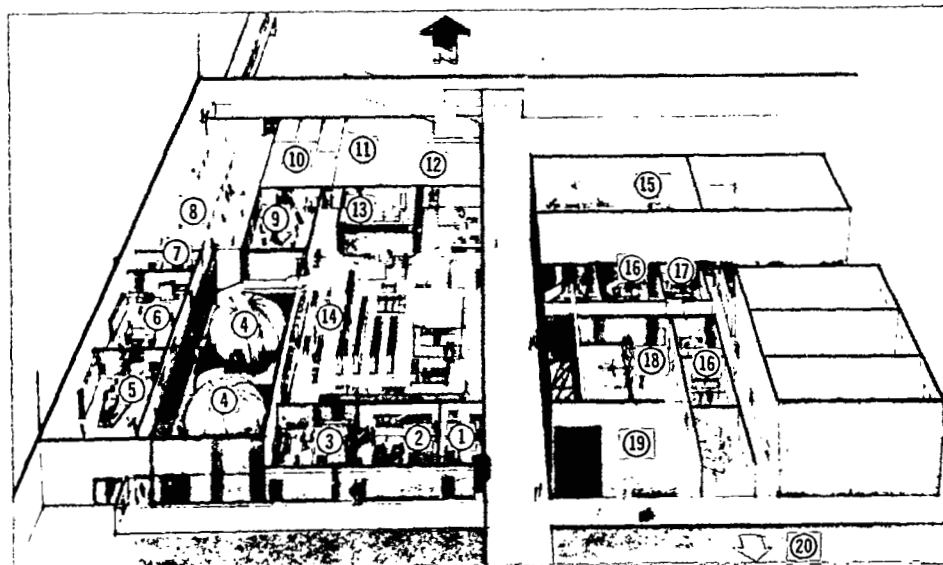
This simulator employs a rear-projection, real-image, out-the-window display system, providing the pilot with a forward 60° field of view. The horizon generator is used to give the pilot attitude cues during both orbital and atmospheric flight simulations and the terrain map and translator are used for landing simulations. Orbital rendezvous and docking simulations have been performed using a target tunnel setup similar to that used for air-to-air combat.

FACILITY LAYOUT

Proposed Flight Simulator Facility

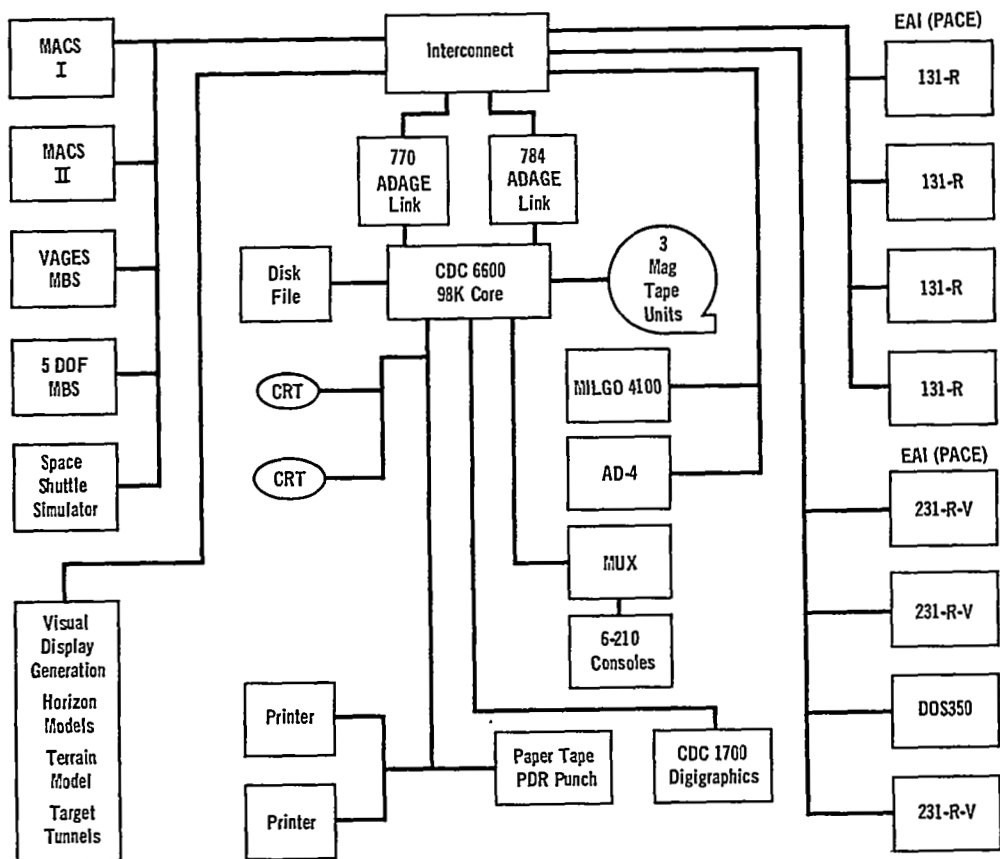
CONSOLIDATED ST. LOUIS LABORATORY MASTER PLAN/May 1970

LEGEND



- ① Security Check Office
- ② Briefing Room
- ③ Control Room
- ④ Manned Air Combat Simulators
- ⑤ VAGES
- ⑥ Technical Work Area
- ⑦ Offices
- ⑧ Desk Area
- ⑨ Space Shuttle
- ⑩ Human Performance Laboratory
- ⑪ Antenna Laboratory
- ⑫ X-ray Laboratory
- ⑬ CEAC Area
- ⑭ Computer Area
- ⑮ Moving Base Simulator
- ⑯ Visual Display Generation
- ⑰ Hydraulic Power Supply
- ⑱ Terrain Map Room
- ⑲ High Bay Area
- ⑳ Future Expansion Area

OPERATIONAL DIAGRAM



MCDONNELL DOUGLAS HOUSTON OPERATIONS SIMULATION FACILITY

REPORTING INSTALLATION: McDonnell Douglas Corporation McDonnell Douglas Astronautics Co. 16915 El Camino Real - Houston, Texas 77058	STATUS OF FACILITY: Active
	COGNIZANT ORGANIZATIONAL COMPONENT: Houston Operations, Dept E931
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Houston Operations, Dept E931 M. E. Fowler Phone: (713) 488-5660

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Houston Operations hybrid simulation laboratory is a general purpose digital and hybrid computation and simulation facility. The primary objective of the installation is the engineering support of Apollo- and Skylab-related contractual work performed by McDonnell Douglas Astronautics Company for NASA/MSD with emphasis on real-time man-in-the-loop simulation of portions of manned spaceflight missions. The general facility consists of a digital and analog computer, with analog interface equipment, and an on-line conversational graphics terminal. Work performed under the Command Module Docking Simulation (CMDS) contract has enabled the addition of a crew station mock-up and a model tunnel with television camera and screen for out-the-window displays.

The facility is capable of operating one hybrid simulation, and when not so utilized, performs digital computation for engineering and administrative support of the Houston operations facility.

The crew station is equipped with the command astronaut's couch, together with sufficient active dynamic controls to affect the CMDS procedural sequences.

HYBRID COMPUTER COMPLEX:

Digital - The digital computer is a CDC 3200 with 32K memory, card reader, line printer, console typewriter, two Model 853 disc units, and one Model 608 tape unit.

Converters - Analog-digital and digital-analog conversions are provided by an ADAGE 660 linkage.

Analog - The 48-amplifier analog computer system is provided by an EAI (PACE) 131-R.

Graphics - The graphics system is comprised of required software to enable generation of dynamics displays on a 21-inch CRT. Conversation is performed using the CDC 3200 console typewriter. Two additional CRT's also receive the computer-generated graphics output. Modifications are currently in progress to implement hardware-generated alphanumerics.

COMMAND MODULE DOCKING SIMULATOR: The Command Module Docking Simulator provides six-degree-of-freedom simulated spacecraft relative motion. A fixed base crew station is equipped with translation and rotational controllers and Flight Director Attitude Indicator displays. Out-the-window visual docking cues are provided by a closed-circuit television system. The simulation is generated by a hybrid computer system.

The equipment for simulating relative spacecraft and target motion includes a Control Data Corporation (CDC) 3200 digital computer system, an EAI 131-R Analog Computer, an ADAGE 660 hybrid interface link, a crew station, and high resolution visual display equipment; such as the TV camera, target model, and cathode ray tube (100-line) monitor. The analog computer is used predominantly as a control device.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$1300	CONSTRUCTION YEAR: 1968 COST \$ 31,500 ESTIMATED REPLACEMENT VALUE \$750,000
CONTRACTOR: Internally Constructed	LOCATION: Houston, Texas
IMPROVEMENTS AND COSTS: (1968) Simulation Equipment, Cost \$10,000; (1969) Simulation Equipment plus computer rental, Cost \$173,000; (1969) Laboratory Equipment, Cost \$6500; (1970) Simulation Equipment plus computer rental, Cost \$202,000; (1970) Laboratory Equipment, Cost \$7000.	

PLANS FOR FACILITY IMPROVEMENTS: Add CDC 3200 interface for I/O discretes; character generator for graphics terminal; oscilloscopes and plug-in.

COMMAND MODULE DOCKING SIMULATOR (CONTINUED)

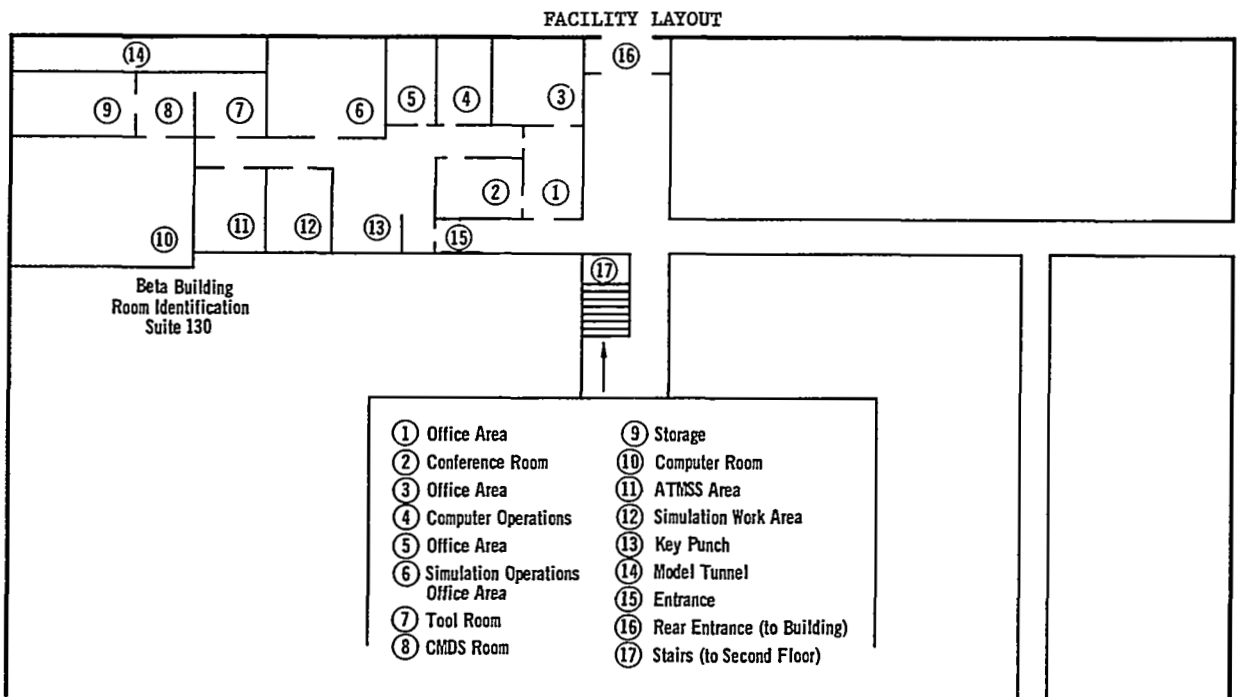
The differential gravity and rotational equations of motion, thrust force definition, control systems models, performance measurement parameters, and visual display drive equations are simulated on the CDC 3200. The data flow between the CDC 3200 and the analog computer is dual and is accomplished via the hybrid interface link.

TESTING CAPABILITIES: This facility is used for support of docking performance definition, control, in-flight operations, and hardware studies. For example, it has been used to demonstrate the feasibility of docking with inhibited thrusters and to provide support data for studies of thruster plume impingement and contamination during docking approach.

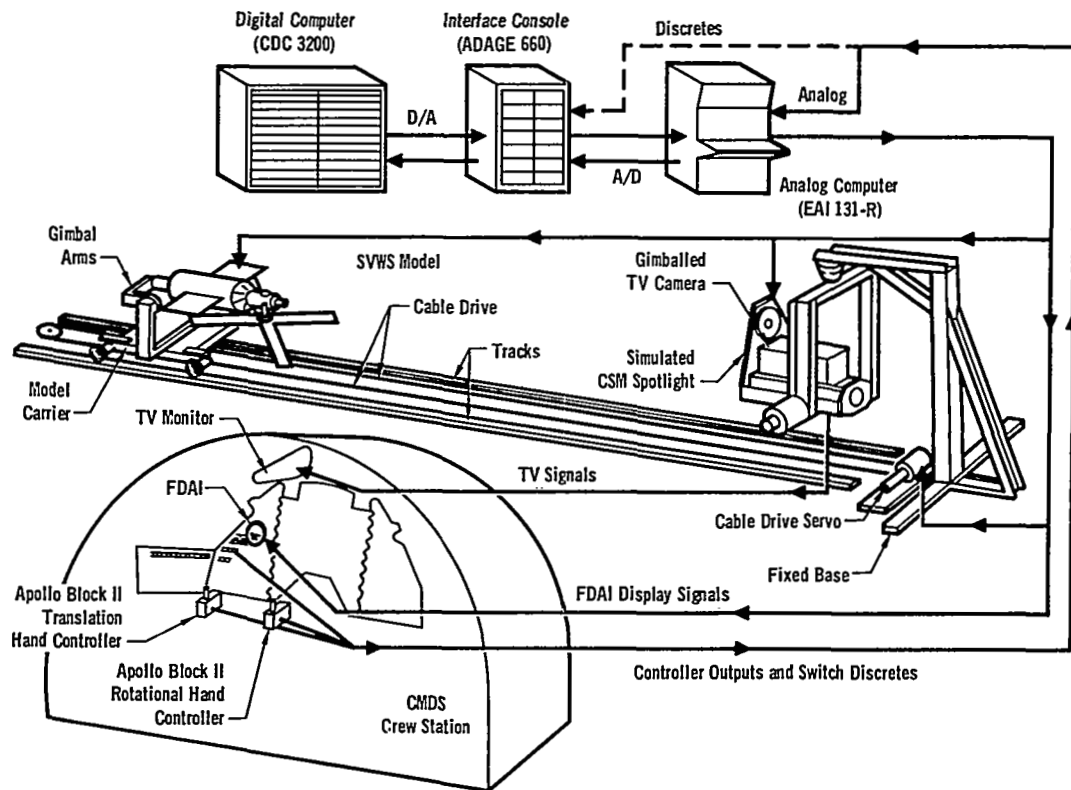
APOLLO TELESCOPE MOUNT SOFTWARE SIMULATOR (ATMSS): The ATMSS complex includes a Control Data Corporation (CDC) 3200 digital computing system, an EAI 131-R analog computer, an ADAGE 660 hybrid interface link, and a crew station as represented by selected panels of the ATM Control and Display (C&D) console. All functional system and ATMSS executive mechanics are simulated on the CDC 3200. The analog computer is used primarily as an interface control device while the ADAGE 660 provides the data flow between the CDC 3200, the EAI 131-R and the crew station. The ATMSS crew station contains active ATM C&D panels which include the Digital Address System (DAS) keyboard and monitor counter, the Attitude Control System (ACS) control panel, the Monitor panel, and the Alert Light panel.

SOFTWARE DESCRIPTION: The ATMSS Real Time Executive Software (RTES) controls the ATMSS operation and timing. In addition, the RTEs decodes, verifies, and stores the DAS commands; processes the C&D panel switch and flag discretes; and scales the C&D panel output parameters for display. The functional system software includes ATMSS initialization, ATMDC primary navigation, Saturn Workshop (SVWS) control modes and maneuvering logic, strapdown references and sensor (acquisition sun sensor, rate gyros, and star tracker) dynamics, the Control Moment Gyro (CMG) attitude control system, the Thruster Attitude Control System (TACS), CMG momentum management software, environmental torque dynamics, and rigid body vehicle dynamics.

SIMULATOR CAPABILITIES: The ATMSS will be used to both introduce and familiarize the Skylab astronauts with the ATM software system and thus to evaluate the man/machine interface. The results of these evaluations will be used to identify areas of operational incompatibility between the flight software and the flight crew. The ATMSS will also be used to develop and verify Skylab A attitude control system in-flight operation and procedures.



OPERATIONAL DIAGRAM



MCDONNELL DOUGLAS SYSTEMS SIMULATION LABORATORY

REPORTING INSTALLATION: McDonnell Douglas Corporation Douglas Aircraft Company 3855 Lakewood Blvd. Long Beach, California 90801	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Flight and Laboratory Development Department 270
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Systems Simulation W. Comley (MS 41-34) Phone: (213) 593-3912

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Systems Simulation Laboratory occupies 5400 square feet in the Flight and Laboratory Development Center. The area has a raised floor and accommodates all of the computing equipment, both analog and digital, used in support of the development cockpit simulators. A large variety of analytical studies are supported as well as the real-time, closed-loop simulation studies.

The equipment complement of the simulation laboratory is composed of the latest and most up-to-date systems. A large complement of cockpit and display system interfacing equipment is also included.

HYBRID COMPUTING SYSTEM: The hybrid computing facility is composed of the following elements: An XDS SIGMA 5 digital computer with 32K words of core memory. The standard peripherals associated with this system are: one card reader, one card punch, one high speed line printer, one 3.5 Megabyte high speed disk, and two tape drives. A small CCI alphanumeric graphic display CRT is used for normal communications.

The interface system is an Astrodata COMCOR CI 510 with 32 channels of A/D and 32 channels of D/A conversion.

The analog system is a COMCOR CI 5000 with 192 digitally controlled attenuators.

ANALOG FACILITIES: Analog facilities consist of 2 MILGO 4100's, 7 CI 175's and 2 Beckman 2132's. The combined analog facilities show a total in excess of 2500 operational amplifiers.

SPECIAL INTERFACING EQUIPMENT: Several cabinets are provided which contain special patch bays for flexible interconnection of various systems, and in addition, contain the special interface equipment, such as 400 Hz modulators and demodulators line driving amplifiers, delay lines, and special display devices. These cabinets are also the termination of over 500 trunks to associated laboratories where several cockpit simulators are located. All computing support to such cockpits is provided by the simulation laboratory.

VISUAL DISPLAY SYSTEM: Visual display to the cockpit simulators is provided by means of 24-inch color television monitors and collimating lens systems affixed to the cockpits for presentation of the forward view for both pilot and co-pilot. The picture is generated by a Redifon Visual System consisting of a 42 x 16 foot solid model and a 6-degree-of-freedom servo controlled color camera system. A unique feature of the system is its scale factor of 750:1. This choice of scale provides an exceptionally high quality presentation for an approach of 2.4 miles.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$4,000	CONSTRUCTION YEAR: 1969-70 COST \$Not Available ESTIMATED REPLACEMENT VALUE \$2,500,000
CONTRACTOR: Internally Constructed	LOCATION: Long Beach, California
IMPROVEMENTS AND COSTS: (1969) Hybrid system added, Cost \$1,300,000; (1970) Redifon visual system added, Cost \$510,000.	

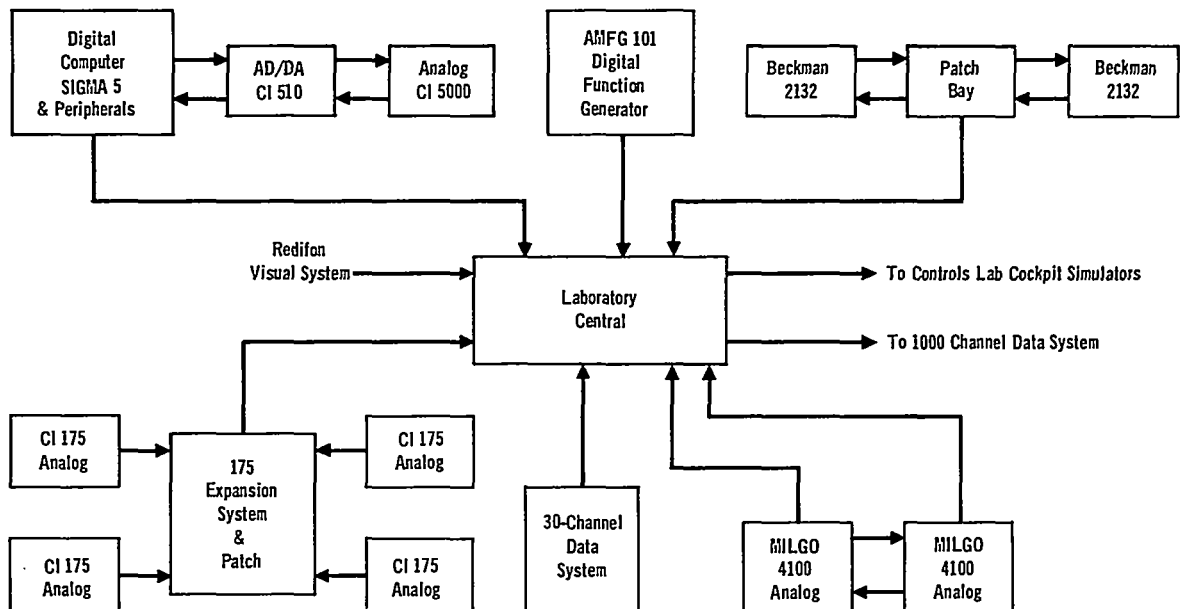
PLANS FOR FACILITY IMPROVEMENTS: Expand capability of digital part of hybrid system.

FUNCTION GENERATION: Function generation capability includes a stand alone system of 12 card set function generators and a digital function generating system capable of providing 32 functions of 24 arguments. These may be functions of either one, two or three variables. This system, the AMFG 101, by Basic Computing Arts utilizes an 8K core mini-computer in a dedicated mode. It is equipped with 24 A-to-D and 32 D-to-A converters. One half of the latter are multiplying DAC's. The system may be used to support several independent simulations.

FACILITY LAYOUT

Not Available

OPERATIONAL DIAGRAM



NASA AMES FLIGHT SIMULATORS

REPORTING INSTALLATION: National Aeronautics and Space Administration Ames Research Center Moffett Field, California 94035	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Director for Aeronautics and Flight Mechanics Simulation Sciences Division
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Chief, Simulation Sciences Division George A. Rathert, Jr., MS N-210-7 Phone: (415) 961-1111

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: Ames Research Center's Flight Simulator facilities are housed in two laboratory areas. (a) The Flight Simulation Laboratory which is a converted airplane hangar equipped with various human-rated piloted simulation devices, visual display generators, a computer complex, and shop facilities. (b) The Flight and Guidance Simulation Laboratory is a large building equipped with several fixed and motion base devices plus a computer laboratory and shop facilities. Some of the equipment operated by the Simulation Sciences Division is described below:

COMPUTER EQUIPMENT: A wide range of analog and digital computers, interfacing, conversion, and readout equipment is available for most simulation problems.

VISUAL DISPLAY SYSTEMS:

Visual Flight Attachment II - This visual system provides the pilot with a color or black and white representation of a visual scene as would be observed during approach, landing, takeoff, and taxiing exercises under varying lighting, cloud, and visibility conditions, by means of a closed-circuit television system. The maximum field of view possible is 46° horizontally by 38° vertically. This system is driven by an electrical servo-position system and has variable scale capability from 1:600 to 1:2000 by changing the model runway length. The television characteristics are as follows:

Scan lines -- 525; Field/Frame Rate -- 60/30; Color (Vidicon/Plumbicon) -- RGB; EIA Resolution (Vertical) -- Approximately 360 lines; EIA Resolution (Horizontal) -- Approximately 450 lines; Model Resolution -- 10 lines per degree from 25 feet altitude to 750 feet at a range of from 200 to 3000 feet.

SCENE MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	35	.014 to 1.25	± 4.5
Velocity (ft/sec)	.53	.093	.5
Acceleration (ft/sec ²)	.8	.24	.45
Frequency* (Hz)	.52	.75	.42
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 100	± 20, -30	+70, -250
Velocity (deg/sec)	114.6	171.9	19.1
Acceleration (deg/sec ²)	240.6	916.8	114.6
Frequency* (Hz)	1.7	8.5	.8

*At 30° Phase lag

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: Not Avail. COST \$ Not
CONTRACTOR: Not Available	ESTIMATED REPLACEMENT VALUE \$ Available
IMPROVEMENTS AND COSTS:	LOCATION: Not Available
Not Available	

PLANS FOR FACILITY IMPROVEMENTS: Modifications are being made continuously to these devices and their specifications are subject to change. Staff personnel are available for consultation with prospective experimenters to assist with planning and scheduling of their experiments.

VISUAL DISPLAY SYSTEMS (CONTINUED)

Visual Flight Attachment III - A servo-driven television camera with five degrees of freedom, together with a lighted model runway on a moving belt (the sixth degree of freedom), is used to acquire a visual scene of landing approach below a 350-foot ceiling. The motion systems are controlled through a general-purpose computer which has been programmed to account for vehicle dynamic response to pilot control inputs. The pilot may be presented with a projected or monitor image as a visual aid in fixed- or moving-base simulators. This system is van-mounted for semi-mobility.

SCENE MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)*	15,000	350	± 250
Velocity (ft/sec)	.5	.5	.33
Acceleration (ft/sec ²)	---	---	---
Frequency (Hz)**	---	1.80	.88
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 30	± 15	± 30
Velocity (ft/sec)	63	63	114.6
Acceleration (ft/sec ²)	---	---	---
Frequency (Hz)	.24	.3	.2

*At scale of 1:300

**At 30° Phase lag

Visual Flight Attachment IV - This visual system consists of a moving belt model of an airfield together with an electrical servo positioner providing variable rate inputs to three linear drives. This visual system provides the pilot with a color representation of a visual scene as would be observed during approach, landing, takeoff, and taxiing exercises under varying lighting, cloud, and visibility conditions, by means of a closed-circuit television system. The maximum field of view possible is 48° horizontally by 39° vertically. Scale of the scene can be varied by changing the belt model. Normal runway length at a scale of 1:2000 is 10,000 feet. The television characteristics are as follows:

Scan lines -- 626/525; Field/Frame Rate -- 50/25 and 60/30; Color (Plumbicon -- RGB); EIA Resolution (Vertical) -- Approximately 450 lines; EIA Resolution (Horizontal) -- Approximately 550 lines; Model Resolution -- 14 lines per degree from 50 feet altitude to 2000 feet at ranges of 250 feet to 5000 feet.

SCENE MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	30	.006 - 1.0	± 3.5
Velocity (ft/sec)	.62	.233	.55
Acceleration (ft/sec ²)	1.62	.5	1.65
Frequency (Hz)			
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 170	± 25	± 170
Velocity (deg/sec)	744.9	200.55	641.76
Acceleration (deg/sec ²)	5730	491.38	
Frequency (Hz)			

SPECIAL SIMULATION EQUIPMENT:

Hydraulic Control Loader System - There are four systems of this type which are used to simulate the "force field" of aircraft flight controls. Performance of this system is outlined below.

Characteristics *	Nominal Deflection	Nominal Force Range	Inertia	Viscous Friction	Coulomb Friction
Lateral (Wheel)	$\pm 80^\circ$	≤ 80 lb	.001 - .03 lb/deg/sec ²	0-0.3 lb/deg/sec	≤ 5 lb
Longitudinal (Column)	9 in. Aft 5 in. Fwd	≤ 90 lb	.01 - .1 lb/in./sec ²	0-1.0 lb/deg/sec	≤ 10 lb
Directional (Rudders)	± 4 in.	≤ 85 lb	**	**	≤ 20 lb

Hydraulic Servo Response: 2 cps pilot-controlled oscillation without loss of force when the amplitude of the oscillation is $\pm 25\%$ full-scale about the trim setting.

* Deflection and force measured at pilot's touch points. The above characteristics are dependent upon the mechanical linkage system used, operated with 1200 psi hydraulic pressure. However, the typical linkage system used at Ames in simulators for large transport aircraft does reflect the above values, which are then only dependent upon the control loader computer variables.

**Information not available at this time.

Control Loader Computer Variables (Each Axis): Scale and Rate, Preload, Cable Stretch, Trim (Auto-pilot Input), Inertia, and Friction

Possible Options: "Boost-off" conditions due to Mach number, flap position, dynamic pressure, etc.

Aircraft Sound Simulators - Simulation of sounds heard in aircraft cockpits is provided by the Ames Aircraft Sound Simulators. All sounds can be individually adjusted for quality and intensity. Frequency-dependent sounds (such as impeller whine) can be set for the required engine simulated. All sounds reaching the pilot's ears are dependent upon simulator construction and speaker location. The following characteristic sounds can be generated.

SOUND CHARACTERISTICS:

Turbojet engines (4), exhaust roar and impeller whine. RPM, idle to 100%/or throttle position (forward and reverse thrust)

Turboprop engines (4), exhaust roar, fixed-pitch RPM, idle to 100%/or throttle position noise, and turbine whine (forward and reverse thrust)

Afterburner roar Afterburner ignited

Air hiss and runway rumble Airspeed

Knock and air flow Landing gear down and locked (3 each)

Thud and rumble Landing gear wheels hit runway (2 each, main)

Runway rumble. Weight on wheels

Air hiss (interior). Air Conditioning system rate

INPUT/OUT CHARACTERISTICS: All solid-state circuitry allowing ± 100 VDC analog inputs. Stereo operation, (i.e., two speaker system, balance control) 50-watts, peak-to-peak output capability.

SOUND EVALUATION TECHNIQUES: Tape input capability connected to sound simulator's output circuitry for comparison checks.

SPECIAL SIMULATION EQUIPMENT (CONTINUED)

Portable Chairs - Six portable chairs are available for research of flight programs in which motion is not an informative cue or for check-out of program prior to use of moving base simulators. They may also be used to determine optimum instrument-panel arrangement. Hand or hand-and-foot controls may be fitted. The instrumentation can include externally-generated displays or star fields, an approach and landing scene, or cathode-ray-tube-presented instrument readings. Four of these chairs may be completely enclosed to isolate the pilot.

SIMULATOR SYSTEMS:

Five-Degree-of-Freedom Motion Generator - Consists of a swinging arm with a choice of two cabs, one simulating a space vehicle and the other simulating an aircraft cockpit. Motion is provided by Ward-Leonard Electrical Servos and torque motors which drive through silent chain or wire rope onto rubber-faced sectors or grooves. An Analog Computer provides closed-loop operation and may be programmed to prevent vehicle systems malfunction. Shutdown capability is provided at several stations and electrical and electronic circuits are used to limit accelerations, velocities, and displacement. Brakes are energized-to-release for fail-safe operation. A qualified physician monitors subject or pilot physiological functions during operations requiring radial acceleration exceeding 2 g's. Cab Number 1 is fitted for high-g simulations and accommodates one man with body-restraint seating, a hand-operated controller, and flight instrumentation as required. A closed-circuit televised view of the subject is usual for monitoring purposes. Cab Number 2 has seating, instrumentation, and controls for one pilot, typical of aircraft. Televised displays are available. Using Cab Number 1, space vehicle launch or re-entry and physiological evaluations may be made. Cab Number 2 provides for evaluating aircraft handling qualities and control systems.

MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral	Arm (Radial)	Arm (Tangential)
Displacement (ft)	None	± 2	None	-	Unlimited
Velocity (ft/sec)		16		-	-
Acceleration (g's from normal)		± 1		6	± 1
Frequency @ 20° Phase Lag (Hz)		.5		Onset - 1.5 g/sec	-
Rotary Motion	Roll	Pitch	Yaw	Arm (Radial)	Arm (Tangential)
Displacement (deg)	± 360	± 52	± 180	-	-
Velocity (deg/sec)	460	115	115	-	143
Acceleration (deg/sec ²)	1030	344	344	-	-
Frequency @ 20° Phase Lag (Hz)	.64	.88	.35	-	-

Flight Simulator for Advanced Aircraft (FSAA) - Provides a piloted transport-type cockpit which can be altered to simulate various types of Advanced Aircraft concepts. The cockpit module is mounted on a six-degree-of-freedom motion platform which is a permanent part of the simulation system. Other sub-systems include the computer, sound system, and an out-the-window visual system.

The motion system is driven electrically in all degrees of freedom. Two tractors move the simulator laterally by means of toothed timing chains which engage a rubber-faced track. Three continuous ball screws raise and lower the vertical platform which is floated on a system of pneumatic equilibrators to unload the screw drive. The longitudinal motion system rides the top of the vertical platform and carries the cockpit and gimbal systems fore and aft. A single ball screw drives the longitudinal platform with the load taken on the ball-bearing lathe-like ways mounted on the vertical platform. The three angular motions are provided by relatively conventional chain-drive gimbals.

The visual display system consists of a 12 x 40 ft model which is televised in color and projected on a screen in front of the cockpit which the pilot views through a collimating lens. The picture has the conventional 525 lines scanned 30 times a second, and covers 48 deg horizontal and 36 deg vertical as seen from the pilot's seat.

A hybrid digital-analog computer provides closed-loop operation. It consists of an EAI 8400 digital computer, and 64 channels each of analog-to-digital and digital-to-analog conversions which connect the EAI 8400 to auxiliary equipment such as analog computers and cockpit instruments.

SIMULATOR SYSTEMS (CONTINUED)

The FSAA is used for studies of stability, loading, and related transport-type aircraft handling, control systems and crew tasks.

MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	± 4	± 5	± 50
Velocity (ft/sec)	6.32	8.65	17
Acceleration (ft/sec ²)	10	12	12
Frequency @ 30° Phase Lag (Hz)	1.8	2.2	1.0
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 45	± 22.5	± 30
Velocity (deg/sec)	100	40	40
Acceleration (deg/sec ²)	230	115	115
Frequency @ 30° Phase Lag (Hz)	3.1	1.5	1.7

Height-Control Test Apparatus - Consists of a single or dual cockpit, a Ward-Leonard Electrical Servo Driven Motion System, visual display system and an analog computer which provides closed loop operation. The cockpit is equipped with an opaque hood for instrument flight simulation. Special visual displays are contact analog and a landing approach image generator which presents scenes to the pilot by means of a closed circuit television monitor. This facility is used for helicopter, V/STOL and large transport research requiring sustained vertical acceleration and visual contact from low altitudes. In this connection, evaluations of instruments and control systems may be accomplished.

MOTION SYSTEM PERFORMANCE

Linear Motion	Displacement (ft)	Velocity (ft/sec)	Acceleration (g's from normal)	Frequency @ 30° Phase Lag (Hz)
Vertical	100	18	$\pm .7$	1.5

Moving-Cab Transport Simulator - Consists of a conventionally equipped side-by-side, two-pilot cockpit, three-degree-of-freedom motion system, visual display, and an analog computer to provide closed-loop operation. Motion is generated by three linear actuators which may be operated in synchronization or differentially through hydraulic servos. The visual system provides the pilot with a color or black and white representation of the visual scene as would be observed during approach, landing, take-off, and taxiing exercises under varying lighting, cloud, and visibility conditions by means of closed-circuit television. The maximum field of view possible is 46° horizontally by 38° vertically. Evaluation of aircraft handling qualities and control systems may be conducted during approach, landing, and taxiing.

MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	None	2	None
Velocity (ft/sec)		-	
Acceleration (ft/sec ²)		0 to 64.4	
Frequency @ 30° Phase Lag (Hz)		.5	
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 9	+14 to -6	None
Velocity (deg/sec)	12.6	12.6	
Acceleration (deg/sec ²)	270	270	
Frequency @ 30° Phase Lag (Hz)	.5	.5	

SIMULATOR SYSTEMS (CONTINUED)

Six-Degree-of-Freedom Motion Simulator - Consists of a one-man cockpit, motion simulator, visual display, and computer. The one-man cockpit is typical of a V/STOL aircraft and is fitted with stick, rudder, and throttle controls and its design permits installation of cockpits of other configurations. The motion system drive is accomplished by Ward-Leonard Electrical Servos and torque motors which drive through silent chains to rubber-faced sectors or to cable-pulling drums. The visual display is used as an approach and landing aid and is presented to the pilot via closed-circuit television. A general-purpose digital or analog computation provides closed-loop operation. Displacement of the visual display to a limit of travel programs the cab to drive to an initial condition of displacement and altitude. This simulator is used primarily for research of V/STOL aircraft approach and landing flying qualities as well as for evaluations of control system characteristics.

MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	± 9	± 9	± 9
Velocity (ft/sec)	9	7.5	8.0
Acceleration (ft/sec ²)	7.5	8.8	9.2
Frequency @ 30° Phase Lag (Hz)	.24	.20	.54
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 35	± 35	± 35
Velocity (deg/sec)	75	173	97
Acceleration (deg/sec ²)	573	258	172
Frequency @ 30° Phase Lag (Hz)	.63	.55	.70

Vertical Acceleration and Roll Device - Is a dynamic flight simulator with vertical translation and roll rotation capabilities. It consists of a two-place, side-by-side cockpit supported on a vertical track. This simulator is normally operated closed-loop with flight dynamics generated on an analog computer programmed to account for vehicle dynamic response to pilot control inputs. Rotary hydraulic servo motors provide linear motion for the vertical excursion, controlled by an electro-hydraulic servo valve, and an electrically controlled linear actuator is used for roll. A television camera is driven closed-loop for acquiring a television monitor view of a model runway and surrounding countryside as a visual aid in landing approach studies. This device is used for aircraft research requiring visual contact and for aircraft, spacecraft, and medical investigations requiring normal and roll accelerations.

MOTION SYSTEM PERFORMANCE

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)		± 10	
Velocity (ft/sec)	None	± 12	None
Acceleration (ft/sec ²)		± 64.4	
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 30		
Velocity (deg/sec)	± 172	None	None
Acceleration (deg/sec ²)	± 172		

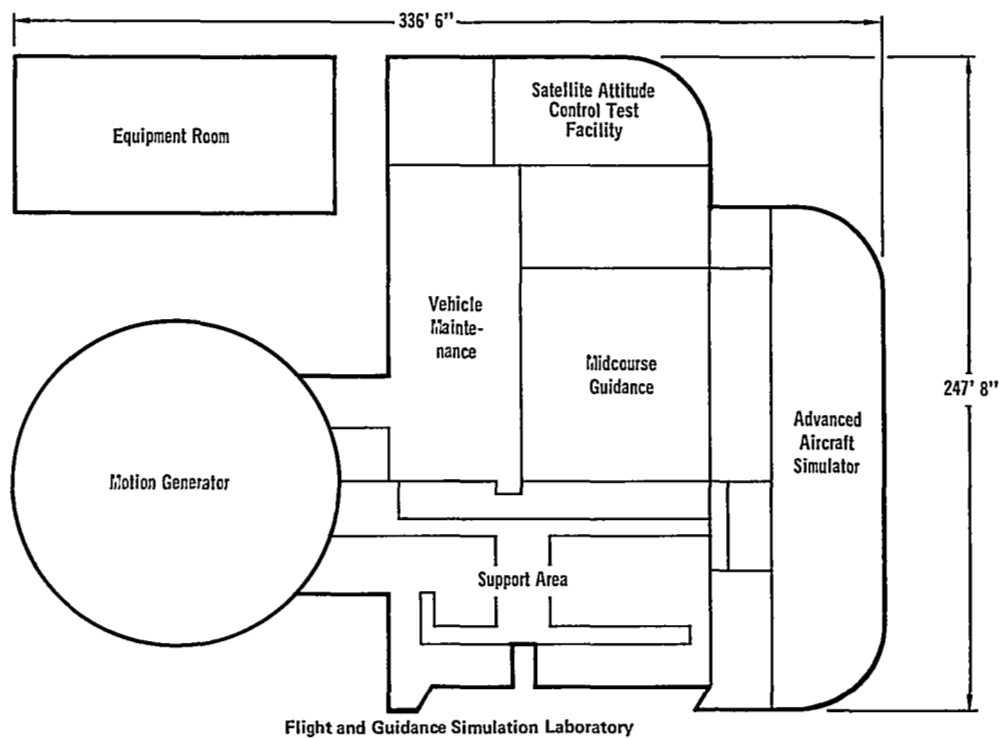
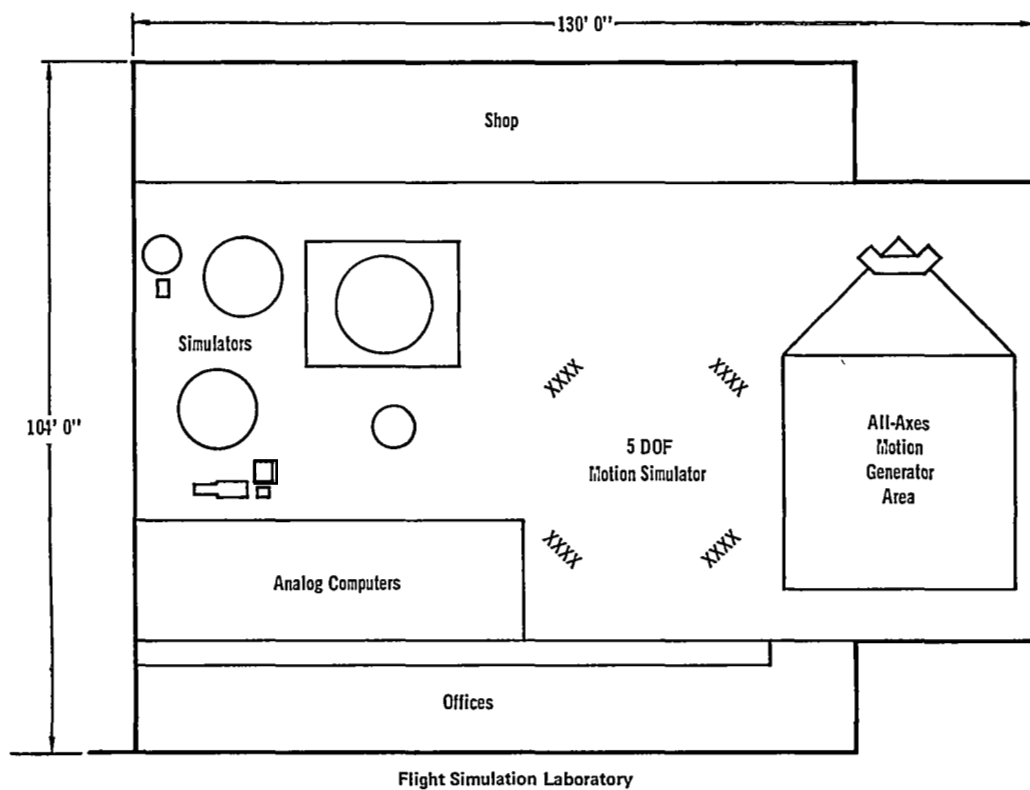
Other Simulators - Simulation of aeronautical and space flight problems is provided by a number of other simulator systems and includes the following:

- Fixed-Base Transport Simulator (No. 2) for aircraft crew task evaluation.
- Midcourse Navigation Simulator for the assessment of space navigation instruments and procedures.
- Flight and Guidance Centrifuge for spacecraft mission simulation.
- Man-Carrying Rotation Device for physiological studies.
- Biosatellite Centrifuge for determination of g tolerance of biological subjects.

SIMULATOR SYSTEMS (CONTINUED)

- f. Environmental Chamber for studies involving altitude, atmosphere composition, or temperature capability.
- g. Portable Chamber for studies involving altitude or atmospheric compositions with centrifugation.
- h. Human Environmental Test Facility for studies involving altitudes, atmospheric composition, and temperature or temperature cycling.

FACILITY LAYOUTS



NASA FRC SIMULATION LABORATORY

REPORTING INSTALLATION: NASA Flight Research Center P.O. Box 273 Edwards Air Force Base California 93523	STATUS OF FACILITY: <u>Active</u>
	COGNIZANT ORGANIZATIONAL COMPONENT: Simulation
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation Laboratory J. P. Smith Phone: (805) 258-3311 ext 684

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Simulation Laboratory is a general-purpose simulation complex, oriented primarily toward but not limited to manned real-time flight simulation. It consists of digital and analog computers, six crew stations, a flying spot scanner visual scene generator, contact analog visual scene generators, various display units, and associated hardware.

The laboratory is capable of operating three hybrid simulations and one analog simulation simultaneously. Visual information from either the flying spot scanner or the contact analogs can be routed to any of the crew stations.

The crew stations are equipped with active flight controls and active flight instruments. With the exception of the PA-30 simulator, which consists of the actual aircraft flight control system, each station is equipped with a variable feel control loader.

COMPUTER COMPLEX:

Digital - The digital computers are: (1) an XDS 9300 computer with 24K memory, three magnetic tape units, one card reader, and a paper tape punch and reader, and (2) an XDS 930 with 32K memory, one magnetic tape unit, one card reader, a paper tape punch and reader, and a 500,000-character random access data file. A line printer is shared between the two computers. The XDS 930 computer utilizes a dual hybrid operating system which permits the simultaneous operation of two real-time programs.

Converters - Analog-digital and digital-analog conversions are provided by two separate XDS interface systems.

Analog - The facility contains four general-purpose analog computers, one EAI 231-R-V, one EAI 231-R, and two ADI AD-4 computers.

SPECIAL SIMULATION HARDWARE:

Flying Spot Scanner - Generates a two-dimensional 525 line black and white television picture from a plain view transparency.

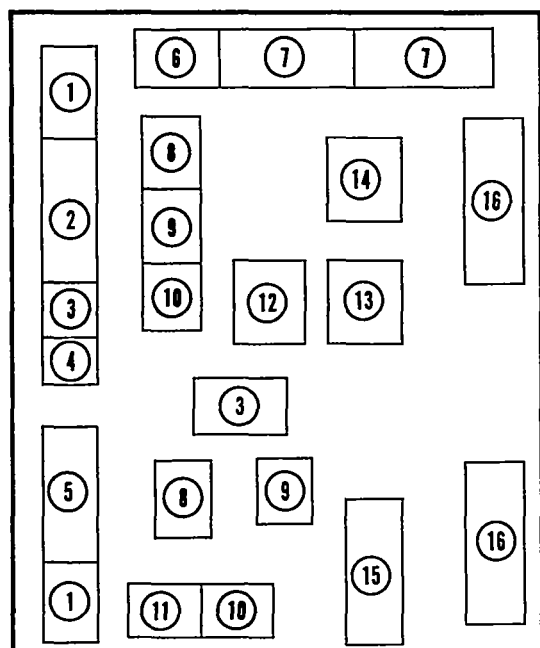
Contact Analog - Generates a 525-line television picture consisting of a ground texture and horizon.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8 HOUR SHIFT): \$4,500	CONSTRUCTION YEAR: 1956-1959 COST \$ 1,580,000 ESTIMATED REPLACEMENT VALUE \$ 2,010,000
CONTRACTOR: Internally Constructed	LOCATION: Edwards AFB, California
IMPROVEMENTS AND COSTS: (1970) Two AD-4 computers, Cost \$315,000.	

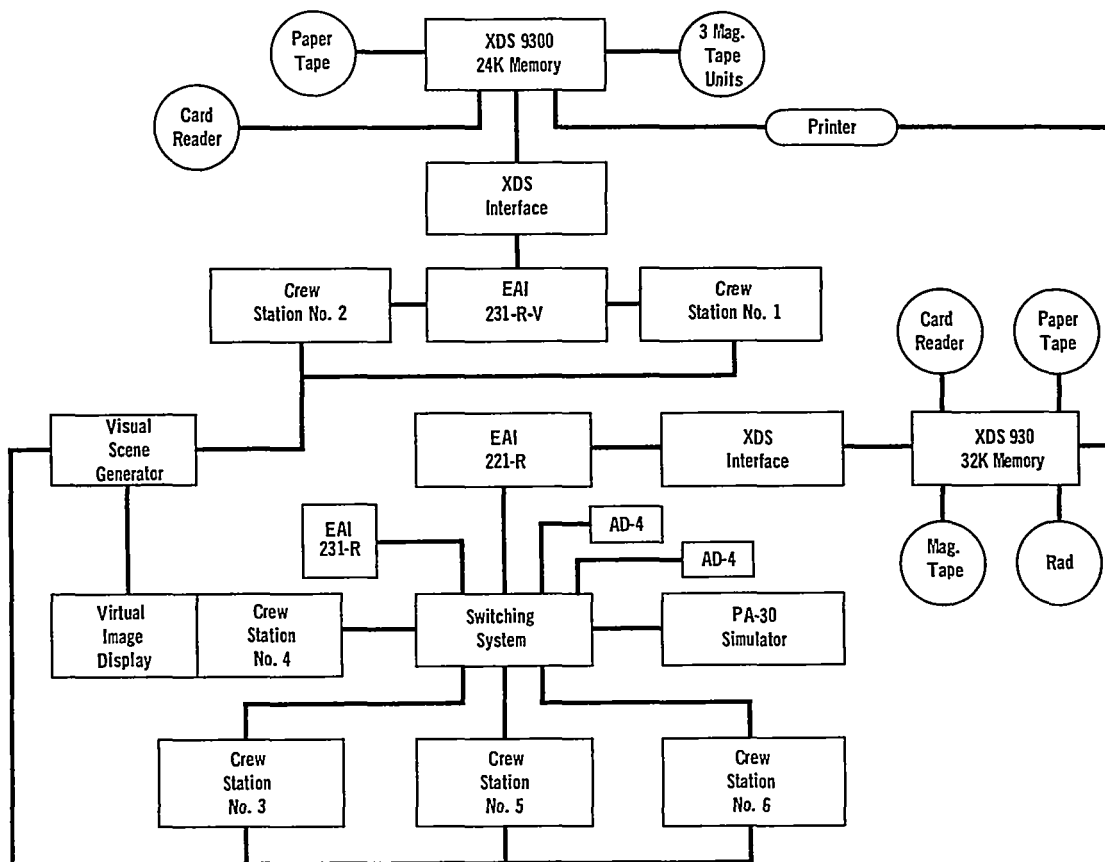
PLANS FOR FACILITY IMPROVEMENTS: Installation of simple motion simulator, improvement of visual displays, and expansion of digital computer capability.

FACILITY LAYOUT



- ① XDS Interface
- ② XDS 930 Digital Computer
- ③ Magnetic Tape
- ④ Radio
- ⑤ EAI 231R-V Analog Computer
- ⑥ Switching System
- ⑦ EAI 231R Analog Computer
- ⑧ Control Desk
- ⑨ Paper Tape
- ⑩ Card Reader
- ⑪ Printer
- ⑫ Crew Station Number 1
- ⑬ Crew Station Number 2
- ⑭ Crew Station Number 3
- ⑮ XDS 9300 Digital Computer
- ⑯ AD-4 Analog Computer
- ⑰ PA-30 Simulator
- ⑱ Visual Scene Generator
- ⑲ Virtual Image Display
- ⑳ Crew Station Number 4
- ㉑ Crew Station Number 5
- ㉒ Crew Station Number 6

OPERATIONAL DIAGRAM



NASA-LANGLEY ATTITUDE CONTROL SIMULATION FACILITY

REPORTING INSTALLATION: National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23365	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Flight Dynamics and Control Division
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Stability and Control Branch E. D. Kersey, Jr. Phone: (703) 827-3036

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Attitude Control Simulation Facility (ACSF) is a multipurpose research complex for the evaluation of spacecraft attitude stabilization and control systems. The 60-foot-diameter sphere provides a solar radiation simulator, a planet radiation simulator, and three star simulators to be used as sources for control system sensors. Scaled dynamic models of complete control systems can be supported by a centrally located airbearing for scaled control system tests, or sensor hardware can be mounted on a three-axis servo table for evaluation. Sensors used include sun sensors, horizon scanners, and three-axis rate platforms. Control logic calculations are performed on-board or remotely with read-out and command telemetry completing the control link. In addition, it is possible to perform control logic calculations with a Control Data Corporation (CDC) 6600 digital computer at the Langley Research Center computer complex, making a wide range of control law applications possible.

The three-axis servo table recently acquired coupled with the data line-buffer system link to the Langley computer complex, becomes an integral part of a diversified simulation system. Actual flight sensor performance can be included along with actuators and control logic to produce a realistic dynamic simulation of control system performance. A wide variety of test equipment and optional modes of operation of the ACSF simulation systems makes it possible to perform component and subsystem evaluations as well as complete control system tests.

SENSOR EVALUATION TABLE CHARACTERISTICS (SERVO TABLE):

Gimbal Freedom (all axes):	± 120 deg
Minimum Smooth Rate (all axes):	0.0004 deg/sec
Maximum Gimbal Rate (outer):	200 deg/sec
(middle):	400 deg/sec
(inner):	200 deg/sec
Position Accuracy:	± 5 sec of arc
Gimbal Servo Bandpass (outer):	14 Hz
(middle):	17.5 Hz
(inner):	27.5 Hz
Maximum Payload Weight:	250 lb
Maximum Payload Envelope:	20 in. (Diameter)
	18 in. (Length)

FACILITY COST HISTORY

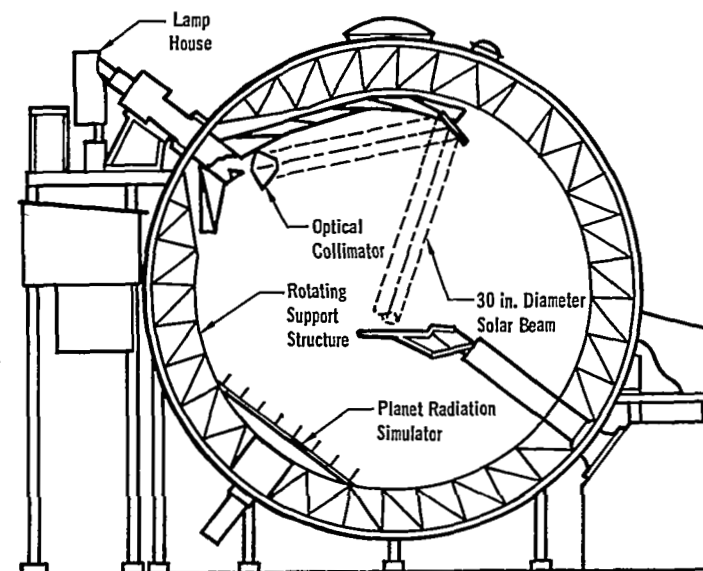
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8 HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1961-1966 COST \$855,000 ESTIMATED REPLACEMENT VALUE \$Not Available
CONTRACTOR: Compudyne Corporation Aerospace Controls General Electric Co.	LOCATION: Hatboro, Penn. Los Angeles, Calif. Cincinnati, Ohio
IMPROVEMENTS AND COSTS: (1965-66) Thermal Control Housing, (1967) Star Simulators (3), (1968) Data Cable and Buffer System, (1965) Elevator, (1970) Three-Axis Servo Table.	

PLANS FOR FACILITY IMPROVEMENTS: Remodel Solar Simulator, Improve Planet Drive System.

ATTITUDE CONTROL SIMULATION FACILITY CHARACTERISTICS

Sphere

Size: 60 ft diameter
 Vacuum: 0.2 torr
 Target supports: - 3-ring planet target support with variable drive; sidereal to 1 rpm
 - Solar target support with constant sidereal drive
 Alignment: Rotation axes are aligned with earth's rotation axis ± 5 arc min
 Model support: 4 and 6 in. airbearings
 Access: 10 and 4 ft dia. hatches



Solar Radiation Simulator

Size: 30 in. diameter
 Source: 20 kW X_E arc lamp
 Uniformity: ± 5 percent
 Intensity: 0.6 solar constants
 Collimation: 3° total angle
 Spectrum: X_E modified by optics

Planet Radiation Simulator

Size: 6 to 20 ft diameter
 Source: Resistance strip heaters
 Temperature: 0-200°F target temperature
 0-70°F between target and background
 Uniformity: $\pm 2^\circ\text{F}$

Star Radiation Simulators

Size: 15 in. diameter
 Source: 18 watt ribbon filament lamp
 Image size: 8 arc seconds
 Collimation: ± 5 arc seconds
 Uniformity: ± 0.1 stellar magnitudes
 Intensity: -2 to +6 stellar magnitudes

Thermal Control Housing

Temperature control: $\pm 9^\circ\text{F}$
 Hoist: 7-1/2 ton monorail traverse

Model Parameters

Max size: 40 ft diameter
 Max weight: 4,000 lb
 Data link: 52 pair cable to strut
 18 channel FM-FM telemetry
 Onboard power: Mercury dipwire power feed

NASA-LANGLEY FLIGHT CONTROL RESEARCH FACILITY

REPORTING INSTALLATION: National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23365	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Analysis and Computation Division
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Analog Computing and Simulation Branch C. N. Valade, Mail Stop 125-B Phone: (703) 827-3203

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Control Research Facility (FCRF) and the Data Reduction Center to which it is appended provide computing equipment and services for all of the scientific computing activity at NASA's Langley Research Center. This combined facility houses an extensive digital computer complex which performs all analytical and data-reduction "batch" processing, services low- and medium-speed remote (open-shop) terminals, and provides "on-line" data reduction to ground-test facilities. Along with an adjacent analog computing facility, the central digital equipment also performs the bulk of all "real-time" computation for research flight simulators located in the FCRF and in several remote buildings.

The original Data Reduction Center also contains significant facilities for centralized digital data recording and telemetry data transcription; however, subsequent descriptions hereunder will be limited to the FCRF and features pertinent to real-time simulation.

FCRF COMPUTATION FACILITIES:

Central Digital Processing - Four Control Data 6000 Series computers operate in a multiprogram, multiprocessor environment to handle the total processing requirements. Multiple-access switches provide data paths from each processor to standard peripherals, bulk storage, and special interfaces such as the Real-Time Simulation Subsystems (RTSS) and CRT Display Controllers. Typically, for simulation, up to three real-time programs are processed simultaneously on a single central processor. Real-time programs operate under the control of supervisor/scheduler software systems, which allows completely independent operation of the real-time jobs as well as independent background use of the same processor for "batch" work on a time-available basis. Two identical simulation subsystems (RTSS) exist and can allow real-time jobs to be run on separate processors. This feature provides redundancy but is also used when greater batch "through-put" can be realized by spreading the memory/time requirements of real-time work over two central processors.

Real-Time Simulation Subsystems (RTSS) - Each of the two RTSS's contains the basic real-time clock and interval timer for synchronous program control. Each contains 80 analog-to-digital input channels, 192 digital-to-analog output channels, 960 discrete inputs, and 960 discrete outputs. The analog interfaces are 15-bit, ± 100 -volt systems with exceptional noise rejection features. Each RTSS job is controlled from one of three control stations which provide basic mode control, and monitoring features including digital and logic readouts, analog time histories, and X-Y plots. Nonreal-time CRT displays adjacent to each control station allow interactive operator control and program changes. Since real-time jobs can be "loaded" in the RTSS area, these features combine to provide an autonomous environment for the simulation programmers.

Analog Computing Facility - Adjacent to the RTSS area, this facility contains three full-expanded EAI 231-R consoles and two GPS 10,000 repetitive-operation computers.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8 HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1966-68 COST \$ Not Available
CONTRACTOR: Basic Construction	ESTIMATED REPLACEMENT VALUE \$ Not Available
IMPROVEMENTS AND COSTS: (1969) Simulation signal distribution system and spherical projection screens.	

PLANS FOR FACILITY IMPROVEMENTS: (1) General-purpose fixed base cockpits, (2) Differential maneuvering simulator, (3) Six-DOF motion base, (4) Ninety-degree virtual image display system.

FCRF COMPUTATION FACILITIES (CONTINUED)

Simulation-Signal Distribution - A manual (patchboard) switching system provides analog and discrete signal interconnection from each RTSS or analog computer to any simulator site within FCRF or to remote simulator sites. The system provides programmable means for allocating RTSS DAC's and ADC's to the three jobs (control stations) on each RTSS and, within the bounds of any given allocation, allows changing jobs on any one control station with no interruption of jobs on the other control stations. The signal distribution system also provides a modest analog interface between digital and analog computers; however, no control provisions exist currently for synchronous operation.

FCRF SIMULATION HARDWARE SYSTEMS:

Fixed-Base Cockpits - Two general-purpose, fixed-base cockpits provide means for basic IFR aeronautic research in applications such as handling qualities and instrument display development. Each of the cockpits can be readily converted from two-seat, wheel-column transport configurations to V/STOL configurations with collective controls or single-seat stick or side-arm controller configurations. Standardized wiring allows quick changes of flight instruments. Each system is equipped with three-axis, programmable, servo-driven (hydraulic) control-force systems which allow simulation of control dynamics and nonlinear effects such as deadband, preload, friction, and cable stretch. Additional computer inputs allow inclusion of kinetic effects such as hinge moments and bob-weights.

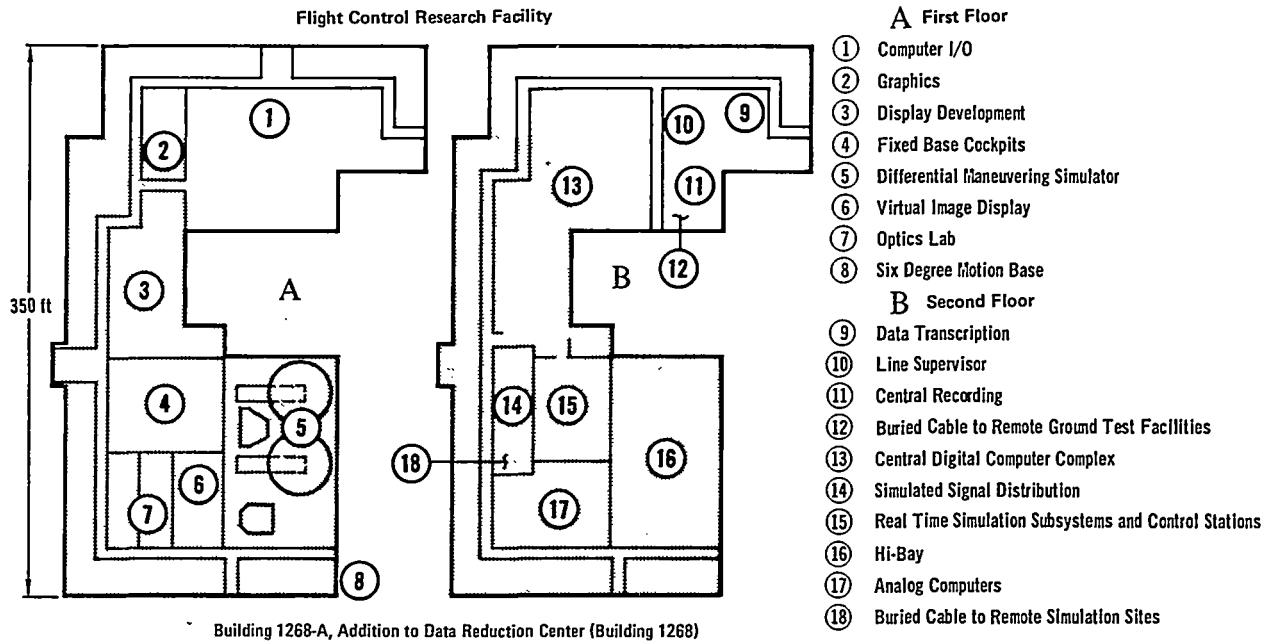
Differential Maneuvering Simulator - This dual fixed-base simulator is a visual display system employing two 40-foot-diameter spherical projection screens in the high-bay area of FCRF. A simulator pilot in each sphere is afforded a wide-angle view ($\pm 170^\circ$ azimuth, $+90^\circ$, -60° elevation) of sky, earth, and a target image representing the vehicle flown by the other pilot. The target image generation and projection systems employ scaled models supported in four-axis gimbal systems, TV camera pickup, and high-intensity CRT projection through two-axis projection-mirror systems which provide line-of-sight positioning to any point within the wide-angle viewing field. Target ranging is accomplished by simultaneous drive of a camera-zoom lens and a large format projection zoom lens to provide a total range ratio of 150:1. At the nearest range, the target image subtends a maximum viewing angle of approximately 12° . The sky-earth projection systems employ mercury arc lamp projection of colored spherical transparencies which provide only rotational cues (pitch, roll, and yaw) with no translation of terrain features. The projection transparencies are driven by four-axis gimbal systems. The arc lamp sources are driven orthogonally relative to the inner gimbal to maintain correct mapping of the spherical transparencies on the spherical projection screen. Projection intensities provide approximately 0.5 foot-lambert target brightness and 0.15 foot-lambert sky-earth brightness. Combined gimbal motions provide continuous rotational capability for vehicle rates up to 8 radians per second in roll and 3 radians per second in pitch and yaw. Vehicle acceleration capabilities are 10, 3, and 3 radians per second squared for roll, pitch, and yaw, respectively. Ranging and line-of-sight positioning provide six degrees of freedom between vehicles with closure rates in excess of 1500 feet per second and relative angular rates in excess of 5 radians per second. Each sphere is currently equipped with a fully instrumented aircraft cockpit with programmable control forces, vertical buffet motion up to 0.5g from 0 to 20 hertz, and pressure-servo controlled g-suit.

All computations for vehicle dynamics, relative geometry, and hardware drive are performed in the central computing complex.

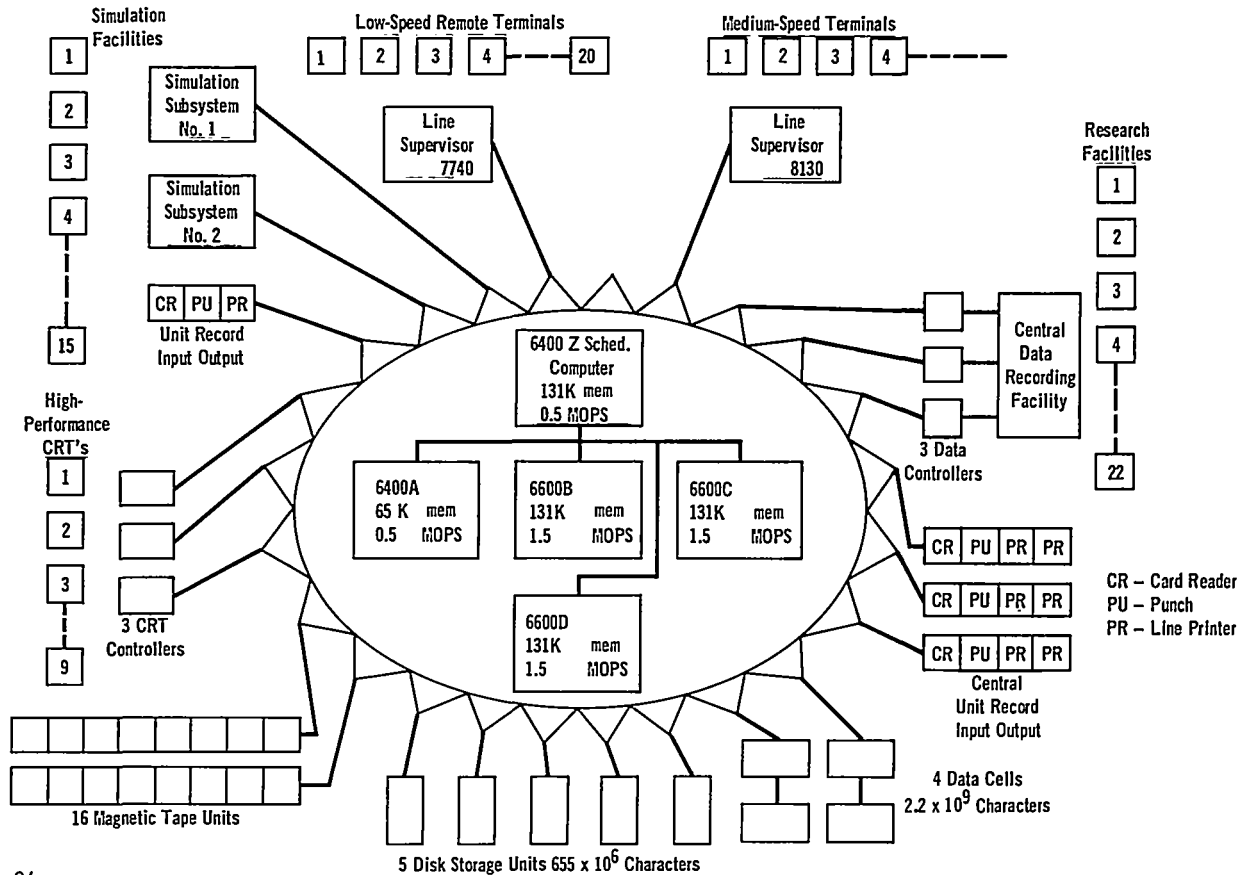
Six-Degree-of-Freedom Motion Base - A standard Singer-Link (synergistic) motion system is currently under procurement for installation in the FCRF high-bay area in mid-1971. After installation, this system will be outfitted by NASA with a cockpit and CRT-virtual-image display system for basic studies of motion-visual effects. The initial display source will be a scaled-model, terrain-scene generator now existing in another facility (Building 1220) which is described in a separate enclosure.

Virtual-Image Display Simulator - An in-house system now under development will provide a 90° refractive virtual-image presentation of mixed sources for general application to space and aeronautical studies. The system will allow simultaneous inputs of terrain-scene, target-vehicle image from high-intensity kinescope projectors, and will include a third input from a gimballed planetarium projector.

FACILITY LAYOUT



LRC DIGITAL COMPUTER COMPLEX



NASA-LANGLEY CMG RESEARCH LABORATORY

REPORTING INSTALLATION: National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23365	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Flight Dynamics and Control Division
OTHER SOURCES OF INFORMATION: NASA TM X-2069 AIAA Paper No. 69-940	LOCAL OFFICE TO CONTACT FOR INFORMATION: Stability and Control Branch C. R. Keckler Phone: (703) 827-3036

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Control Moment Gyro (CMG) Research Laboratory is a facility which permits the real-time evaluation of full-scale CMG's or other activator hardware in a simulated dynamic environment. It is composed of CMG hardware, a Control Flight Test Bed (CFTB) with torque measuring fixtures (TMF's), control electronics, buffer system, an analog computer and a variety of component test setups.

The CFTB is a three-axis servo table which provides the dynamic environment for the full-scale control system hardware. This hardware is mounted in TMF's on the inner gimbal of the CFTB. The CFTB is linked to the real-time simulation computer through the buffer system.

COMPUTER EQUIPMENT:

Digital - The Langley Research Center's real-time computer complex provides a Control Data Corporation (CDC) 6600 digital computer for real-time mission simulations.

Analog - An EAI 680 system is a component of the CMG Research Laboratory and provides the required analog computation.

Software - Present computer simulation programs for this facility model the spacecraft dynamics, the orbital environment, crew motion disturbances, and the control computer and steering laws. The computer solves the spacecraft equations of motion and commands the CFTB to duplicate the vehicle motion. Simultaneously, the real-time computer generates control commands which are sent to the control hardware. The resultant control torques are measured by the TMF's and sent to the real-time computer to close the simulation loop.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1967-68 COST \$ Not ESTIMATED REPLACEMENT VALUE \$ Available
CONTRACTOR: Eastern Const. Corp. Cohoon and Heasley, Inc.	LOCATION: Newport News, Va. Cambridge, Mass.
IMPROVEMENTS AND COSTS: (1967) Control Moment Gyros (CMG's), (1969) Control Flight Test Bed (CFTB), (1968) Buffer System, (1969) Computer Equipment, (1969) Access Platform and Hydraulic Room	

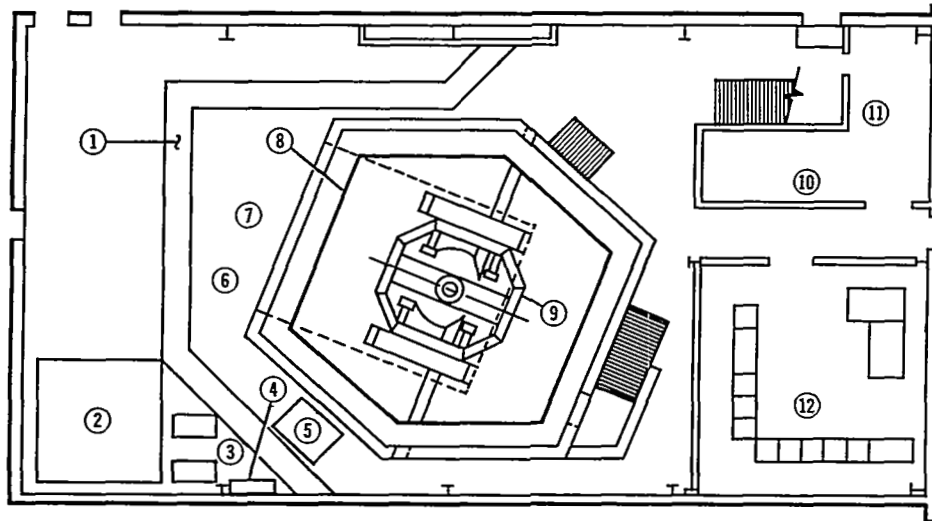
PLANS FOR FACILITY IMPROVEMENTS: Completion of Hybrid Computation capability and establishment of electronics evaluation laboratory. Establish test area for evaluation of second generation CMG Hardware.

EQUIPMENT PERFORMANCE CHARACTERISTICS:

<u>CFTB Test Load</u>	<u>CFTB Gimbal Drive</u>
Capacity: 2,500 lb Envelope: 8 ft diameter sphere Slip Rings: 150	Inner: 2 dc torquers, continuous freedom Middle: 2 hydraulic torquers, $\pm 85^\circ$ freedom Outer: 2 hydraulic torquers, $\pm 85^\circ$ freedom
<u>Torque Measurement Fixture (TMF)</u>	<u>*CFTB Gimbal Performance</u>
Max torque: 200 ft-lb Resolution: 0.02 ft-lb Accuracy: 0.1 percent of reading or 0.02 ft-lb Rise time: 20 ms Resonant frequency: 10 Hz	Position threshold: 0.0005° Position accuracy: 0.001° Maximum drift: 0.01° per hr IG max rate: 25° per sec MG and OG max rate: 10° per sec Minimum rate: $0.0005 \pm 0.0001^\circ$ per sec **Position tracking accuracy: 0.005° **Rate tracking accuracy: 0.02° per sec
* Applies to all three gimbals unless otherwise stated ** $0 = 1^\circ \sin 4t$ drive signal	

TESTING CAPABILITIES: The facility is used for full-scale control component and system tests, and can perform real-time mission simulations with prototype control hardware when operated with a Control Data Corporation (CDC) 6600 digital computer in the Langley Research Center real-time computer complex. Centralization of control electronics for the various hardware and of the buffer system permits operation and monitoring of all functions by one operator, thus improving setup and running efficiency.

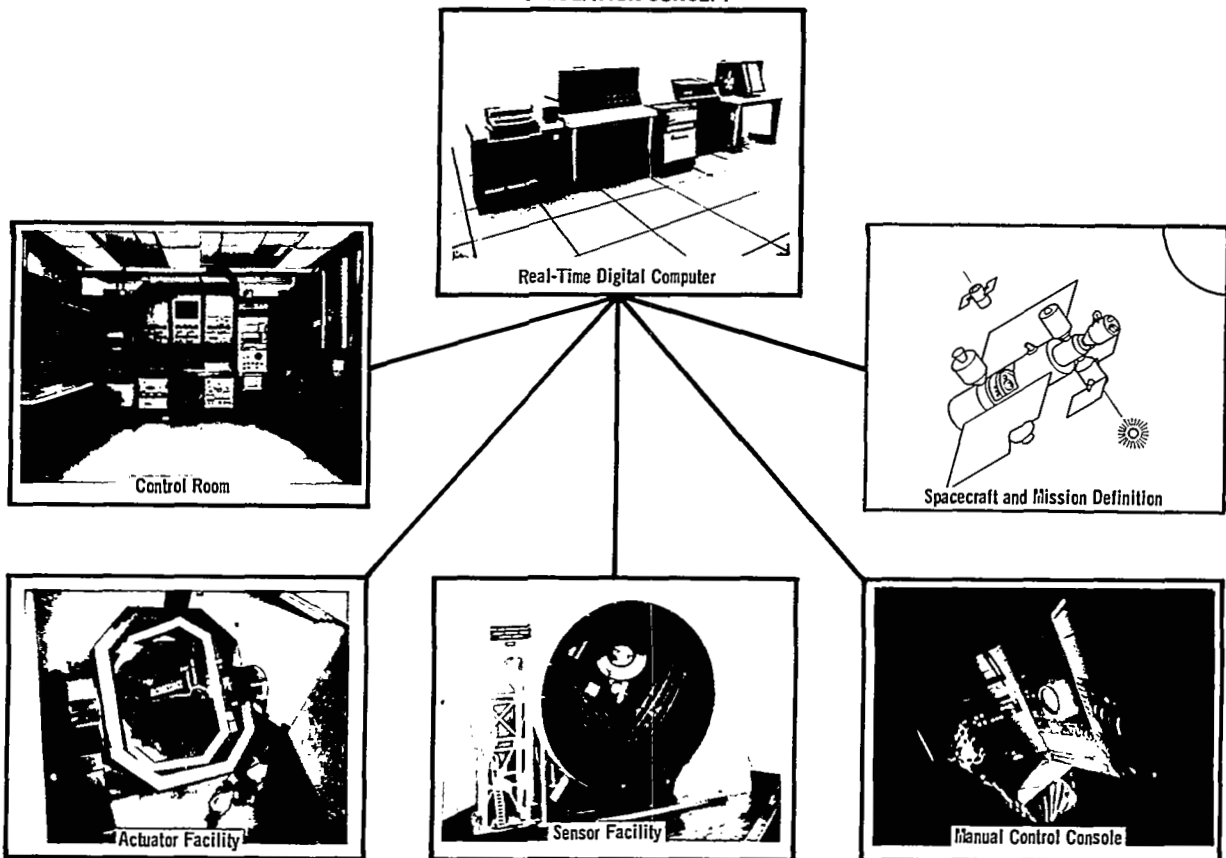
FACILITY LAYOUT



Legend

- ① Utility Trough
- ② Static Test
- ③ Motor Generator
- ④ Console
- ⑤ Hydraulic Supply
- ⑥ Removable Wall Sections (16 ft Wide)
- ⑦ CFTB Enclosure
- ⑧ Seismic Mass Foundation
- ⑨ CFTB
- ⑩ Electronics Evaluation Area
- ⑪ Pilot Control Console
- ⑫ Control Room

OPERATIONAL DIAGRAM SIMULATION CONCEPT



NASA-LANGLEY SIMULATION RESEARCH LABORATORY

REPORTING INSTALLATION: National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23365	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Analysis and Computation Division
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Analog Computing and Simulation Branch C. N. Valade, Mail Stop 125B Phone: (703) 827-3203

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: This facility operates several simulators which include a Transport Aircraft Simulator (TAS), a Tactical Effectiveness Simulator (TES), and a Foot-Controlled Maneuvering Unit (FCMU) Simulator, all of which are of the fixed-base type with cockpits, visual systems, and analog and digital computers.

COMPUTER EQUIPMENT: This Laboratory, approximately 800 feet from the Flight Control Research Facility, houses a major share of the early, fixed-base flight-simulator hardware at NASA's Langley Research Center. It is linked to central simulation computers in FCRF by buried cable. The Laboratory contains central interface equipment for buffering and conditioning of analog and discrete computer signals from FCRF and for distribution of these signals to the several simulators.

Central Signal Conditioning and Distribution - This equipment includes 220 amplifiers for buffering long lines analog signals, two small analog computer consoles for simulator tests, 25 channels of servo equipment for analog to synchro conversion, solid-state analog to synchro conversion, and three, 3-axis euler angle transformation computers. This equipment, along with computer signals to and from central computers in FCRF, is shared among the several simulators via a cable-patching system for signal distribution.

SPECIAL SIMULATION EQUIPMENT:

Terrain Scene Generator - This equipment, originally developed for lunar-vicinity visual scene generation, consists of two TV camera transports for translation motion, gimballed optical probes (3-axis) with an 875-line, black and white orthicon camera on each, and four scaled models of lunar terrain. One of the models is spherical with painted features, the other three are spherical segments with scaled, relief topography. An earth model segment, added recently, provides a 300:1 representation of a STOL aircraft complex for aircraft approaches and landings. Translation capability of the camera transport (40 ft longitudinally, \pm 3 ft laterally, 2 ft vertically) precludes go-around capability. Work now underway will convert the pickup system to use a color camera. Video distribution lines provide capability for transmission of the scene to several locations within the B-1220 Simulation Laboratory, to FCRF, and to the Rendezvous Docking Simulator in Building 1244.

Fixed-Base Cockpits - Several study stations, equipped for signal distribution and communications, exist to accommodate simple cockpits for instrument cue studies. One of these stations is currently in use for space shuttle simulation. Others have been used previously for handling qualities and control studies of aerospace vehicles such as HL-10, Apollo-Parawing, V/STOL, variable-stability helicopter, and Apollo Telescope Mount.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: Not Avail. COST \$ Not ESTIMATED REPLACEMENT VALUE \$ Available
CONTRACTOR: Not Available	LOCATION: Not Available
IMPROVEMENTS AND COSTS: (1963) Transport Aircraft Landing Simulator, (1964-65) Terrain Scene Generator Model/Transport, (1967) Tactical Effectiveness Simulator, (1969) Foot Controlled Maneuvering Unit Simulator, (1969-70) Signal Buffering and Conditioning Equipment.	

PLANS FOR FACILITY IMPROVEMENTS: Not Available

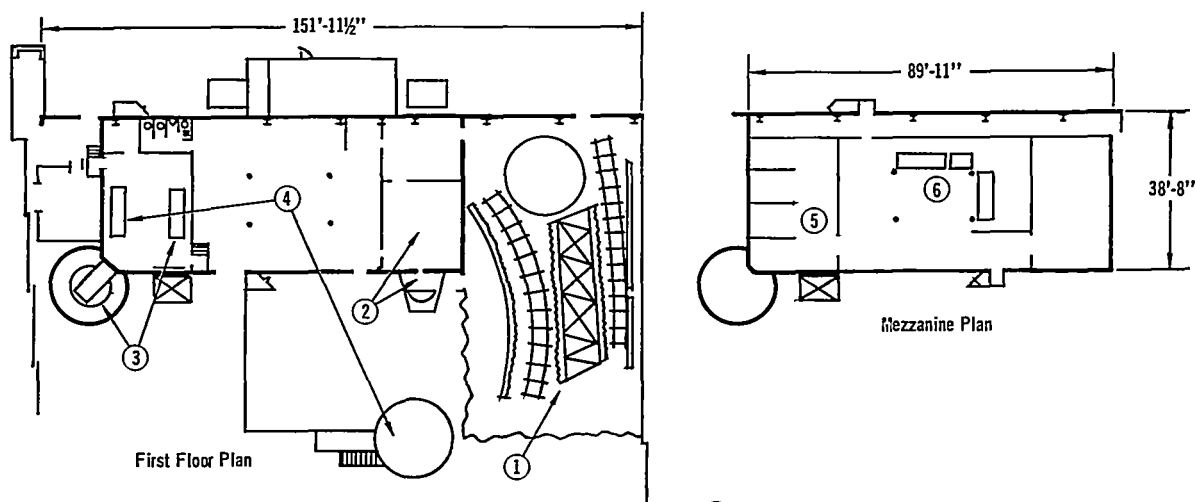
TRANSPORT AIRCRAFT SIMULATOR (TAS): This device is basically a DC-8 flight simulator, built by Curtiss-Wright Electronics Division and originally modified for use in Supersonic Transport studies. The system contains a fully-instrumented cockpit, NAV-AIDS simulation of OMNI-ILS ground stations and data-phone interface used in the mid-1960's to link the SST simulation with an Air Traffic Control Simulator at FAA's NAFE Center near Atlantic City, New Jersey.

This simulator has been used for a wide variety of transport aircraft research studies and is currently used predominantly for Blown-Flap STOL research. A CRT/Virtual-Image window display is tied to the Terrain Scene Generator for visual landing simulation studies.

TACTICAL EFFECTIVENESS SIMULATOR (TES): This simulator, developed as a forerunner to the Differential Maneuvering Simulator in FCRF, provides wide-field visual display (on a 20-foot diameter projection screen) of a target aircraft, sky-earth-horizon optical projection, and a limited-field (approximately 34 degrees) kinescope projection of terrain imagery. The target image presentation employs a gimbaled model, 675-line vidicon camera and high-intensity kinescope projection via a single mirror mounted in a 2-axis gimbal which provides correct line-of-sight. Range effect is created by either a range bed motion of the camera or continuous raster-shrinkage in the target projector or a combination of both. While only one visual scene is presented, an instrumented control station aft of the prime cockpit allows independent control of the second (target) vehicle in the central computer program. The basic equipment used in this simulator came from a surplus gunnery trainer (F-151) built by Rheem Corporation, approximately 1950 vintage.

FOOT CONTROLLED MANEUVERING UNIT (FCMU) SIMULATOR: A second, modified F-151 system has been equipped for studies of space locomotion involving foot-controlled devices. This display system, located in a separate 20-foot diameter projection screen, employs the basic range bed, kinescope and 2-axis mirror system for target image projection as in TES except for the absence of raster-shrinkage ranging. Inertial frame reference is provided by a two-axis, shadow mask (optical) projection of a featureless terrain-horizon.

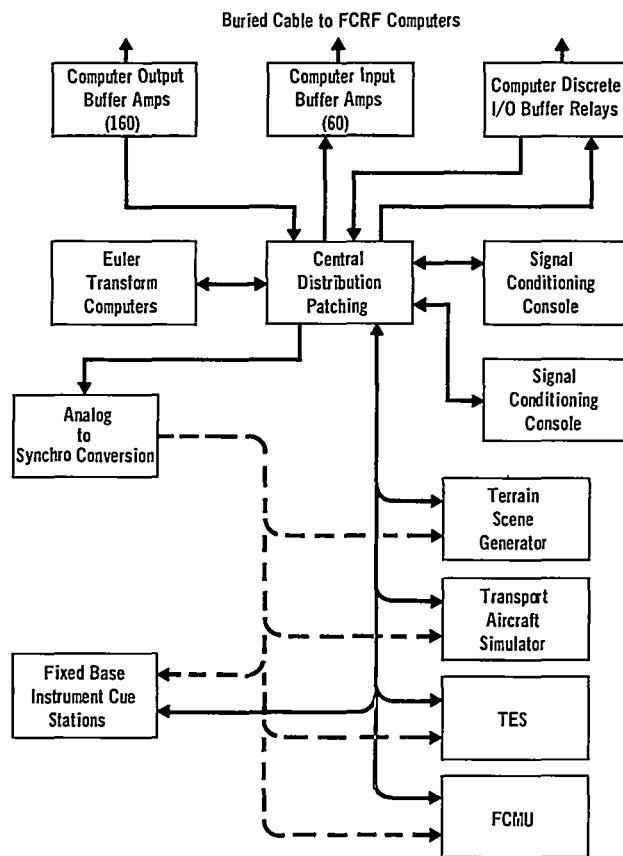
FACILITY LAYOUT



Legend:

- | | |
|------------------------------------|--|
| ① Terrain Scene Generator | ④ Foot Controlled Maneuvering Unit (FCMU) Simulator |
| ② Transport Aircraft Simulator | ⑤ Fixed Base Cockpits |
| ③ Tactical Effectiveness Simulator | ⑥ Central Signal Conditioning and Distribution Equipment |

OPERATIONAL DIAGRAM



NASA-LANGLEY RENDEZVOUS DOCKING SIMULATOR

REPORTING INSTALLATION: National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23365	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Simulation and Human Factors Branch
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation and Human Factors Branch Max C. Kurbjun Phone: (703) 827-2710

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Rendezvous Docking Simulator provides the motion in six degrees of freedom. Angular motion is provided through three interconnecting gimbals. Longitudinal and lateral motions are obtained by a carriage-rail arrangement and vertical motion is achieved through a drum-cable arrangement. The above concept produces independent motion in all six degrees of freedom.

COMPUTER EQUIPMENT: The Langley Digital and Analog Computer Complex provides CI 5000, CI 150 and EAI 231-R computer systems and peripheral equipment as required for solution of real-time simulation problems.

MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	± 75	± 20	± 6
Velocity (ft/sec)	6	6	4
Acceleration (ft/sec ²)	6	6	6
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	Continuous	Continuous	Continuous
Velocity (deg/sec)	57.3	57.3	57.3
Acceleration (deg/sec ²)	57.3	57.3	57.3

Note: All performance figures are maximum values

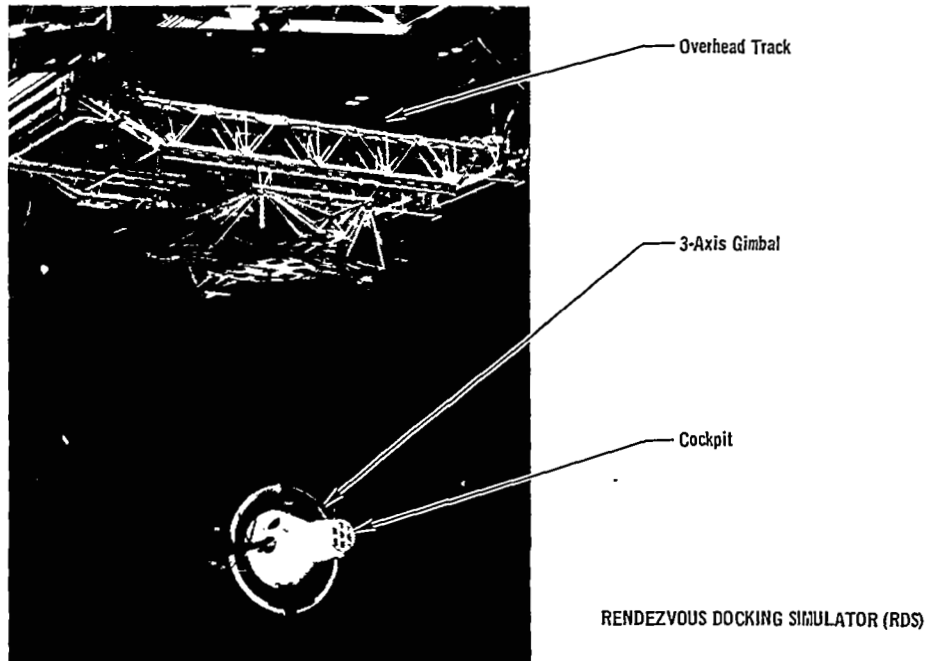
TESTING CAPABILITIES: The facility will accept a one- or two-man cockpit. Visual cues are presented by the real-world environment, by closed-circuit TV, or by cockpit instruments. The facility is used for space orbital docking simulations, aircraft handling evaluations, and for basic motion studies research.

FACILITY COST HISTORY

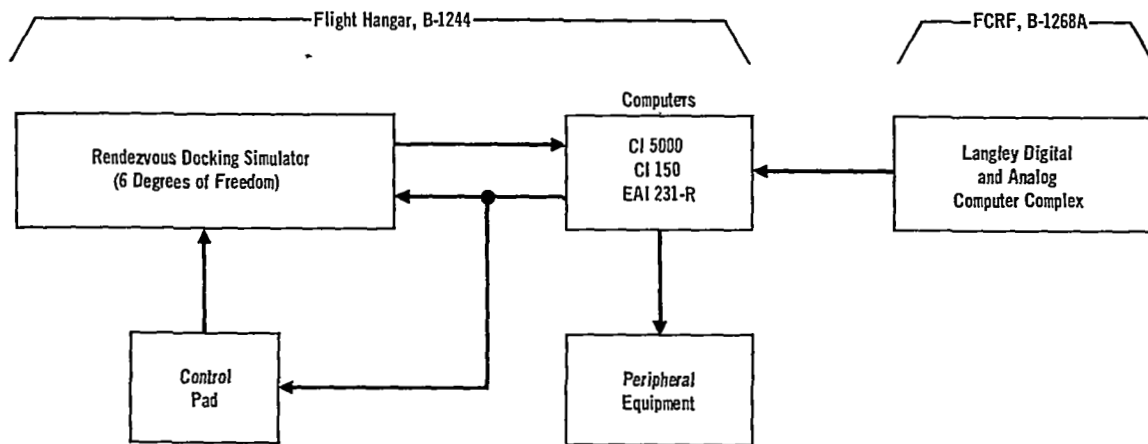
AVERAGE ESTIMATED OPERATING COST (TYPICAL 8 HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1963 ESTIMATED REPLACEMENT VALUE \$ Available
CONTRACTOR: Jered Industries	LOCATION: Birmingham, Michigan
IMPROVEMENTS AND COSTS: (1969) New attitude servos and extensive wiring. Also replaced lateral drive pre-amps.	

PLANS FOR FACILITY IMPROVEMENTS: Modify to accept several aircraft-type cockpits.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



NASA-MSFC COMPUTATION LABORATORY PHYSICAL SIMULATION FACILITY

REPORTING INSTALLATION: National Aeronautics & Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	STATUS OF FACILITY: Active
	COGNIZANT ORGANIZATIONAL COMPONENT: Computation Division, S&E - Comp
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation Branch, S&E - Comp - S, Bldg. 4663 Mr. M. H. Knighton Phone: (205) 453-1383

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The simulation facility is comprised of three hybrid computer complexes, two fixed-base simulators, one moving base simulator, a link six-degree-of-freedom motion system, two SMK-23 model units, one SMK-43 visual simulator, two Eidophor projectors, one Farrand "Pancake" Virtual Image Lens system, one target motion system, and other associated hardware. All computers and simulator equipment terminate at central trucking stations to provide maximum flexibility of equipment for engineering studies.

HYBRID COMPUTER COMPLEXES: The facility operates three hybrid computers, which are a DDP 116 system, an EMR 6050 system, and an EAI 8900 system.

Digital - Several general purpose digital computers provide required digital solutions to simulation problems at the facility. These systems are tabulated below, along with notes on their design features.

GENERAL-PURPOSE DIGITAL COMPUTERS

	RAY 520	RAY 520	ASI 6050	EAI 8400	EAI 640	PB 250	PDP-8	PDP-8	DDP 116
MEMORY CAPACITY, WORDS	20K	160K	32K	32K	160K	6Ka	4K	4K	16K
ACCESS TIME, MICROSEC	2	2	1.9	1	1.6	12	2	2	17
FLOATING-POINT ARITHMETIC	b	b	HARD WIRED ^c	HARD WIRED ^c	d	d	d	d	d
CARD READER, CARDS/MIN	600	600	600	600	400				
CARD PUNCH, CARDS/MIN	300	300	300	300					
PAPER TAPE					YES	YES	YES	YES	YES
MAGNETIC TAPE UNITS	3	2	3	4	2	1			3
HIGH SPEED PRINTER, LINES/MIN	600	600	600	1400	300				
DISK			YES	YES	YES				

a SERIAL DELAY LINE MEMORY

b MICROSUBROUTINE

c FOR GREATLY INCREASED ARITHMETIC SPEED AND MEMORY CAPACITY IN HYBRID COMPUTATION

d SUBROUTINE

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: COST \$ Not
CONTRACTOR:	ESTIMATED REPLACEMENT VALUE \$ Available
IMPROVEMENTS AND COSTS: Not Available	LOCATION:

PLANS FOR FACILITY IMPROVEMENTS: A new lunar terrain map of the Fra Mauns region is under construction for simulations involving operation of the Lunar Roving Vehicle.

HYBRID COMPUTER COMPLEXES (CONTINUED)

Analog - A wide range of general-purpose analog equipment is available and includes the items listed below.

GENERAL-PURPOSE ANALOG SIMULATION EQUIPMENT

ANALOG CONSOLES	OPERATIONAL AMPLIFIERS	INTEGRATORS	SERVO-SET POTENTIOMETER	ELECTRONIC MULTIPLIERS (TOTAL PRODUCTS)	ELECTRONIC RESOLVERS	FUNCTION GENERATORS $y = f(x)$	COMPARATORS (RELAY AMPS)	FUNCTION SWITCHES	PATCHABLE LOGIC
EAI 81 (8812)	330	60	240	48	6 ^b	15	30	24	YES
EAI 82 (8812)	330	60	240	48	6 ^b	15	30	24	YES
EAI 83 (8812)	330	60	240	48	6 ^b	15	30	24	YES
EAI 84 (8812)	330	60	240	48	6 ^b	15	30	24	YES
EAI 60 (680)	141	30	120	24	0	18	24	24	YES
EAI 62 (680)	156	30	120	24	0	18	24	24	YES
EAI 30 (231-R)	120	30	100 ^a	0	0	10	10	8	NO
EAI 40 (231-V)	200	30	150 ^a +20 ^a	15	3 ^b	10	10	12	YES
EAI 42 (231R-V)	216	30	170 ^a	30	3 ^b	10	10	12	YES
EAI 43 (231R-V)	216	30	170 ^a	30	3 ^b	10	10	12	YES
EAI 44 (231R-V)	216	30	150 ^a +20 ^a	30	3 ^b	10	10	12	YES
EAI 45 (231R-V)	216	30	150 ^a +20 ^a	30	3 ^b	10	10	12	YES
EAI 50 (221-R)	72	18	90 ^a	9	0	6	10	9	NO
EAI 51 (221-R)	72	18	90 ^a	9	0	6	10	9	NO
ADI 95 (9500)	256	64	150	30	0	0	20	10	YES
IR-10'S (10)	146	62	162 ^a	17	0	23	5	6	NO
SMALL AD'S (3)	128	38	120 ^a	12	0	10	0	32	NO
TRUNKING STA.	152	0	0	47	0	30	0	0	NO

a NOT SERVO SET

b INCLUDING ALL MULTIPLIERS

HYBRID COMPUTER COMPLEXES (CONTINUED)

GENERAL-PURPOSE ANALOG SIMULATION EQUIPMENT

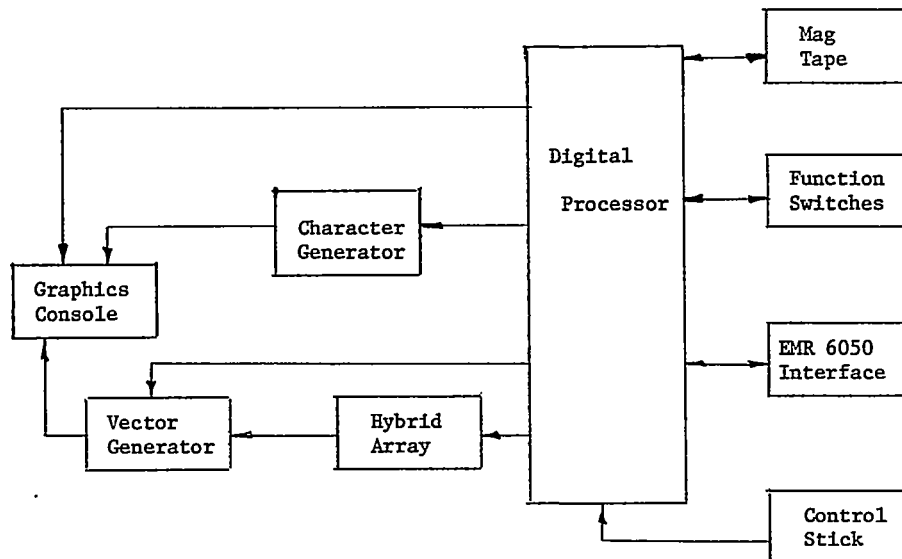
	ANALOG CONSOLES	OPERATIONAL AMPLIFIERS	INTEGRATORS	SERVO SET POTENTIOMETER	ELECTRONIC MULTIPLIERS (TOTAL PRODUCTS)	ELECTRONIC RESOLVERS	FUNCTION GENERATORS $y = f(x)$	COMPARATORS (RELAY AMPLIFIERS)	FUNCTION SWITCHES OR RELAYS	PATCHABLE LOGIC
COM 50	35	8	32	4	1	0	2	4	YES	
EAI 31	150	40	150 +20 ^a	12	0	10	10	20	NO	
EAI 32	170	30	150 ^a	0	0	10	10	20	NO	
EAI 33	170	30	150 ^a	24	0	10	10	20	NO	
EAI 34	170	30	150 +20 ^a	24	0	10	10	20	NO	
EAI 35	170	30	150 +20 ^a	36	0	10	10	20	NO	
EAI 46	200	40	150 +20 ^a	24	3	10	10	20	YES	
EAI 70	120	24	128	12	3	6	0	0	YES	
EAI 85	220	45	180	32	0	0	24	18	YES	
TOTALS	5032	957	2740 1342 ^a	667	46	297	359	420		

a NOT SERVO SET

Graphics - An ADAGE Graphics Terminal (AGT-30) computer system is equipped with a full set of software, magnetic tape system, assembler, compiler and display software. It has the capability of displaying three-dimensional information with rotation and translation in all three axes. The system components include: (a) A digital processor provides extensive transfer logic and addressing capability. It features an 8K - 30 bit memory with a 2-microsecond register-to-register transfer. Its peripherals include a magnetic tape, a set of discrete function switches, a light pen, and a control. (b) A hybrid array solves a transformation matrix for output to a vector generator. The vector generator takes the desired end points of vectors and converts them to proper signals for driving a display scope. (c) A character generator (with 64 character sets) allows alphanumeric characters to be drawn rapidly under hardware control. The AGT-30 is interfaced to an EMR-6050 digital computer, which in turn is linked as a hybrid computer to several analog computers.

HYBRID COMPUTER COMPLEXES (CONTINUED)

ADAGE GRAPHICS TERMINAL



LUNAR ROVING VEHICLE SIMULATOR: The Lunar Roving Vehicle Simulator is composed of several modular elements, each of which performs a specific function.

Its computer system consists of five large-scale analog computers, a digital computer, and the necessary conversion equipment. These computers solve the equations representing the forces exerted on the vehicle, produce drive signals for the visual display system and the motion system, and provide data acquisition and analyses of the driver's performance.

A visual display is generated on a modified SMK-23 which was obtained as excess equipment from the Air Force. A foam rubber three-dimensional terrain model of a typical rough lunar area was constructed in-house on a scale of 100:1. Terrain sensors, developed in-house, maintain contact with the terrain model. Strain gauges attached to the terrain sensors produce voltages which are fed to the computer system as ground elevation inputs to the wheels. A gimbaled optical system driven from the computer provides visual attitude cues while movement of the terrain model and the viewing television camera provides the visual translational cues. The view seen by the camera is televised to a monitor in front of the driver's station located on a six-degree-of-freedom motion system. A virtual image lens is mounted on the front of the television monitor to provide a realistic out-the-window view to the driver.

LUNAR ROVING VEHICLE SIMULATOR (CONTINUED)

SMK-23 TERRAIN & LANDING VISUAL SIMULATOR

MODEL SCALE		TRANSLATION			ROTATION			
		RANGE		VELOCITY	ACCEL	ANGLE	RATE	ACCEL
3000:1	X	13 mi	280 mi/h	900 fps ²	PITCH		± 25°	± 64°/SEC
	Y	6 mi	= 430 fps	= 27 g				
	Z	22 ft .2000 ft	48 fps	500 fps ² = 15 g				
150:1	X	4000 ft	14 mi/h	45 fps ²	ROLL	= 60°	± 172°/SEC	± 500°/SEC ²
	Y	1800 ft	21.5 fps	= 1.4 g				
	Z	1.5 ft .100 ft	2.4 fps	25 fps ² = .75 g				
DEPTH OF FIELD IN THE MODEL 11 in INFINITY								
RESOLUTION HORIZONTALLY: 400 LINES								
OPENING f/55								
FIELD-OF-VIEW 38° VERTICAL x 50° HORIZONTAL								

The driver's station which is mounted on the motion system is an accurate replica of the central portion of the Lunar Roving Vehicle. A prototype hand controller, provided by the contractor, is installed on the driver's station and provides the driver's inputs to the computer for throttle, steering, and braking of the vehicle. Computer outputs displayed on instruments to the driver provide only the vehicle velocity, but in the near future will also provide distance, navigation, and power information as required.

A six-degree-of-freedom motion system provides motion cues to the driver as he changes speed and direction and as he rides up and down hills. Complete information is provided in pitch and roll, but the heading and the three translational motions are "washed-out" so that only acceleration cues are felt by the driver.

MOTION SYSTEM PERFORMANCE

LINEAR MOTION	LONGITUDINAL	VERTICAL	LATERAL
Displacement (ft)	± 4	+3.25, -2.50	± 4
Velocity (ft/sec)	± 2	± 2	± 2
Acceleration (ft/sec ²)	± 19.3 (± .6g)	± 25.8 (± .8g)	± 19.3 (± .6g)
ROTARY MOTION	ROLL	PITCH	YAW
Displacement (deg)	± 22	+30, -20	± 32
Velocity (deg/sec)	± 15	± 15	± 15
Acceleration (deg/sec ²)	± 50	± 25	± 50

Payload = 20,000 lb.

LUNAR ROVING VEHICLE SIMULATION (CONTINUED)

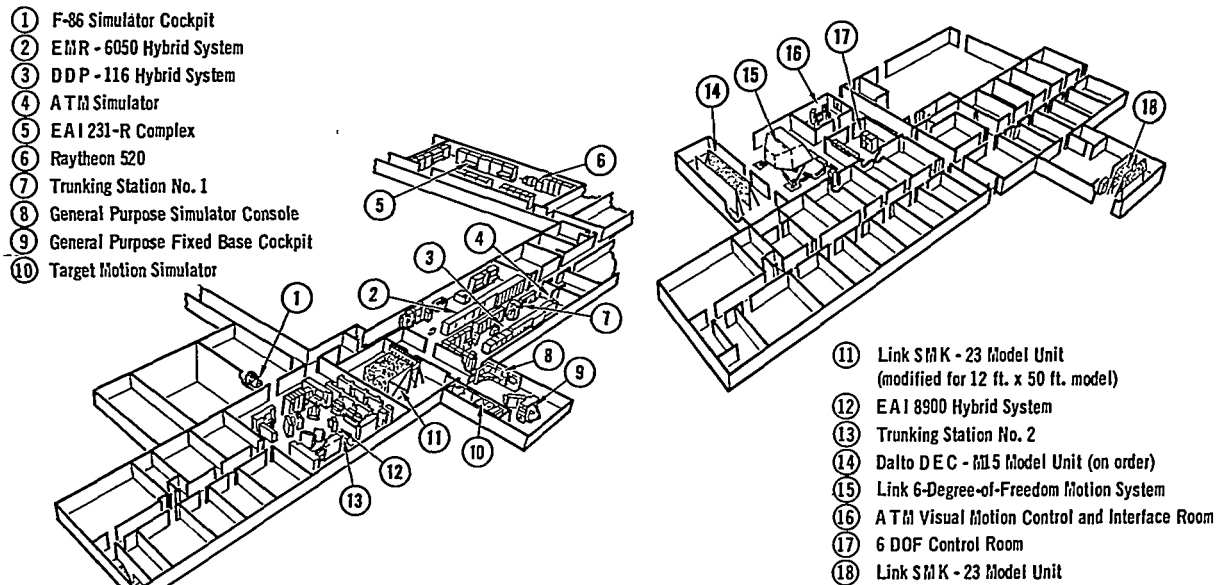
This total system has been used to evaluate the candidate hand-controller parameters. These parameters are friction and breakout forces and location of soft stops in the throttle; spring forces and soft stop location in the steering; the actuation force on the brake; and the location on the brake of an inhibit switch which cuts off drive power when the brake is actuated.

Studies have been conducted to evaluate the crew station layout, control console layout and functions, the navigation system, and crew procedures for particular operations and system failures.

Some typical programs in which this facility has shown its simulation capabilities are listed below:

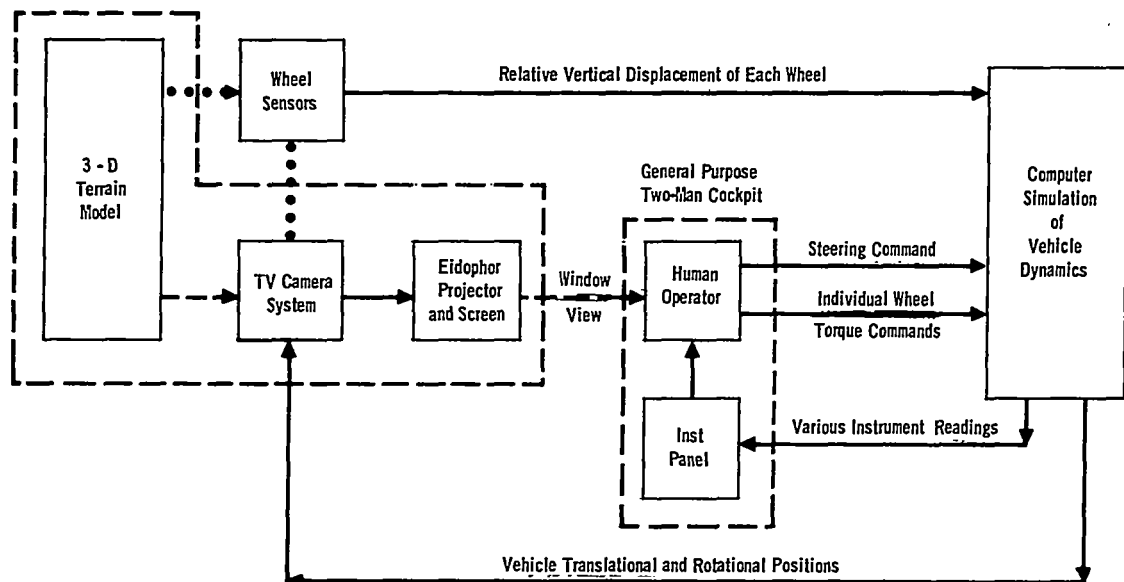
PROJECT	PARTICIPANTS	DATES	SPECIAL EQUIPMENT	APPROX. VALUE	MSFC PROCURE-MENT COST	PRESENT STATUS
1. ORBITAL DOCKING	ASTR	1962-64	(1) TV WITH RASTER CONTROL (2) TARGET MOTION SIMULATOR (3) F-86D COCKPIT	\$200K	\$12K	(2) & (3) OPERABLE
2. SATURN V. PILOTED-CONTROL STUDY	ASTR	1964	CONTROL PANEL (ASTR)	\$15K	NIL	PROJECT COMPLETED IN 1964
3. RESUABLE ORBITAL TRANSPORT	ASTR	1965-66	(1) SMK-23 LANDING SIMULATOR (2) 2-MAN CREW STATION	(1) \$350K (2) \$75K	(1) \$67K (2) \$50K	NOW USED FOR S&E - AERO SHUTTLE SIMULATION
4. LRV	ASTH-S	1964-70	(1) MODIFIED SMK-23 (2) LUNAR MODEL (3) 6 DOF MOTION SYSTEM (4) FARRAND PANCAKE	(1) \$375K (2) \$40K (3) \$240K (4) \$35K	(1) NIL (2) NIL (3) \$240K (4) \$35K	IN USE FOR LRV
5. LRV REMOTE CONTROL	ASTN-S ASTR-G	1969-70	(1) CONTROL STATION, TV, & TELEMETRY-COMP (2) TEST VEHICLE	(1) \$150K (2) \$50K	(1) \$110K (2) \$20K	CHECKOUT
6. SHUTTLE LANDING	AERO-D	1970-	(1) 2-MAN CREW STATION (2) SMK-43 LANDING SIMULATOR	(1) \$75K (2) \$150K (EST.)	(1) \$50K (2) NIL	IN OPERATION

FACILITY LAYOUT



MSFC Computation Laboratory Physical Simulation Facility

OPERATIONAL DIAGRAM



Typical Simulator Application for a Lunar Roving Vehicle

NADC COMPUTER SIMULATION FACILITY

REPORTING INSTALLATION: Naval Air Development Center Warminster, Pennsylvania 18974	STATUS OF FACILITY: Active
	COGNIZANT ORGANIZATIONAL COMPONENT: Systems Analysis and Engineering Dept.
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Computer Simulation Facility H. G. Tremblay Phone: (215) 672-9000, ext 2258

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Computer Simulation Facility is a scientific computing facility established to support research, development, test, and evaluation programs as well as management and data processing programs. It performs mathematical analysis, conducts analytical research and development, using computer and simulator techniques. It operates centralized computers and simulators and performs research, design, and construction of laboratory computational equipment. The facility conducts total mission computer-simulation programs in the form of large, real-time, man-in-the-loop programs where typically data flows from an EAI 8812 analog computer through the hybrid equipment and electronic linkage system to the CDC 6600 digital computer where it is operated on. After the digital computer solves the equations for which it is programmed in FORTRAN, COMPASS, or machine language, the data flows back through another separate electronic linkage system and hybrid equipment to the analog computer and acts as a forcing function on the equations which are set up on that computer. In the hybrid equipment area, equipment is designed, developed, and fabricated to perform real-time computation and simulation of physical systems and to process large quantities of experimental data. Development of techniques and software implementation are carried out on digital, hybrid, and analog computers. In the data processing area, technical as well as management-type data processing programs are programmed and operated. Signal Processing Facilities are also provided to process data made in the field on magnetic tape.

HYBRID COMPUTER COMPLEX:

Digital - The digital capability includes two CDC 6600 computer systems sharing 125K of extended core storage. Each 6600 has 65K of central memory, 10 peripheral processors and 12 I/O channels. Also provided are 2 card punches, 3 line printers, 3 card readers, 2 drum storage units, a dual CRT console, 8 magnetic tape units (9 channel) and 2 units (7 channel), 2 disk files, a graphics terminal, and 5 teletypes. Five 211 remote terminals are provided. An EAI 640 digital computer is provided for extending the hybrid capability and control of the EAI 8812 computers, and for graphics, digital simulation, and interfacing.

Graphics - The graphics system is established around two DEC 338 Display Systems. Each Display System includes a main display CRT with up to 8 remote CRT's; a 16K, 12 bits/word memory; two 96K disks; an ASR 33 teletype; 64 channels of A/D; 3 channels of D/A; 36 switches (remote); a high speed paper tape reader/punch; a 12-bit/word interface; 24 switches (local); and a high speed multiply/divide capability. An Evans and Sutherland high speed display and slave Vector Generator is also provided.

Analog - Four fully expanded and one partially expanded EAI 8812 analog computers are provided. These computers are interfaced with the CDC 6600 and EAI 640 digital computers.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING TIME (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: Not Avail. COST \$ ESTIMATED REPLACEMENT VALUE \$ Not Available
CONTRACTOR: Not Available	LOCATION: Not Available
IMPROVEMENTS AND COSTS: Not Available	

PLANS FOR FACILITY IMPROVEMENTS: Not Available

HYBRID COMPUTER COMPLEX (CONTINUED)

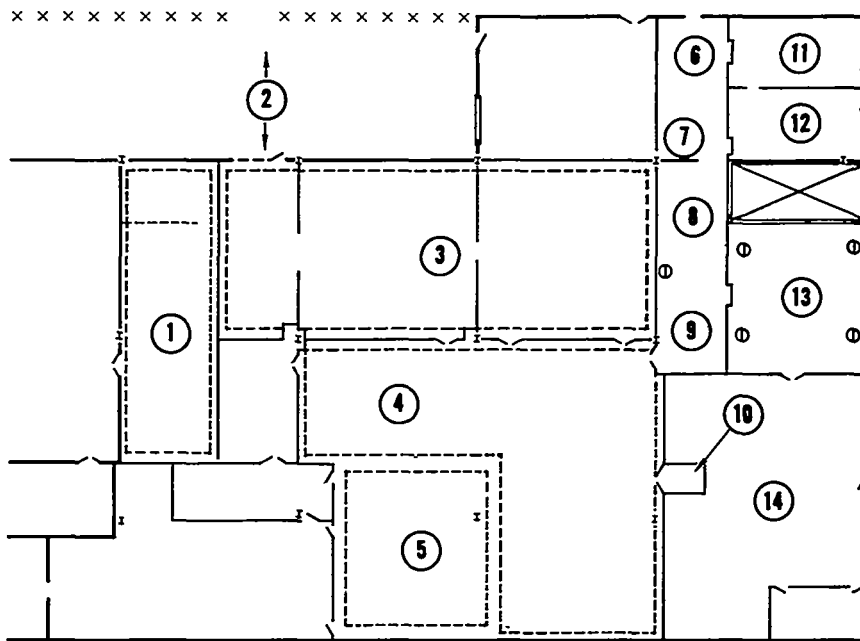
Function Generation - An ACFG (Analog Computer Function Generator) is provided to generate arbitrary functions of from one to three input variables using Rubin's and Chapelle's methods. In addition to its high speed of operation, which prevents unwanted phase problems and yields the same accuracy for both rapidly and slowly changing independent variables, the ACFG combines the repeatability and change-over speed of the digital computer with the rapidity of parallel analog computations. The ACFG is accurate since it may store approximately 25,000 function values in its digital section. It is continuous in a piecewise linear sense along any line of single variable and provides a continuous hyperboloidal surface between the four breakpoints. This approach yields fast generation of continuous functions coupled with the extreme accuracy of a digital computation.

SPECIAL SIMULATIONS:

Aircraft and Air Weapon System Simulation - Analog and digital computers are used with sophisticated interface and display equipment to combine the best features of analog and digital computation for man-machine aircraft and weapons systems studies. A typical weapons system simulation uses an EAI 8812 Analog Computer, a CDC Digital Computer System, a simulated cockpit, a DEC 338 Programmed Buffered Display System, D/A and A/D converters and miscellaneous hybrid and display peripherals to comprise the overall real-time simulation.

Air-to-Air Combat Simulation - The Air-to-Air Combat Simulation was developed to provide the Navy a tool for studying visual air combat between opposing fighter aircraft. Due to the significant influence of the fighter pilot on the nature and outcome of combat in this environment, the simulation has taken the form of a two-cockpit, real-time device in which pilots can engage in one-to-one dogfights. Results are then subjected to various types of analysis in the general areas of fighter aircraft performance engagement tactics or weapon system utilization.

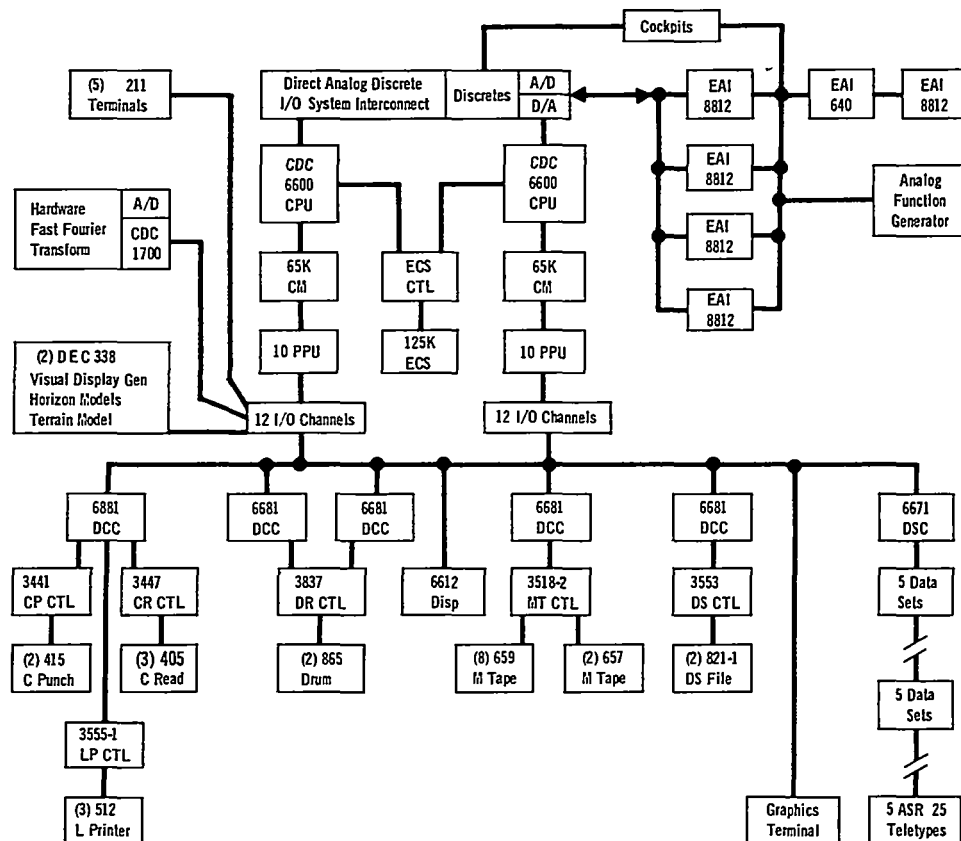
FACILITY LAYOUT



- ① IBM 360/25 (to be phased out)
- ② Access Aisle
- ③ Two CDC 6600's
- ④ Simulation Area *
- ⑤ CDC 3300 (to be phased out)
- ⑥ Xerox
- ⑦ Consumables Storage
- ⑧ User Interface
- ⑨ User Office
- ⑩ Ramp
- ⑪ EAM Room
- ⑫ Keypunch Room
- ⑬ Offices
- ⑭ CSF Main Office

* (5) EAI 8812 Analog Computers
Special Hybrid Equipment.
Analog Function Generator.
(2) PDP8's and Graphics
Displays, Cockpits.
Air-to-Air Combat Simulation
Hardware Fast Fourier
Transform

OPERATIONAL DIAGRAM



NAR ENGINEERING SIMULATION AND COMPUTING LABORATORY

REPORTING INSTALLATION: North American Rockwell Corporation Columbus Division 4300 E. Fifth Avenue Columbus, Ohio 43216	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Missiles Research and Engineering Department 65
OTHER SOURCES OF INFORMATION: Engineering Computing Laboratory, J. C. Haliano, Group 767	LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation Laboratory, L. H. Gale, Group 767 Phone: (614) 231-1851

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Simulation Laboratory is a general-purpose facility equipped to simulate manned and unmanned vehicle real-time motion dynamics. It consists of an analog/hybrid computing facility, a visual flight simulator (VFS), a tactical weapons simulator (TWS) and a four-degree-of-freedom dynamic flight simulator (DFS).

ANALOG/HYBRID COMPUTING FACILITIES: Automated simulation services are provided for the visual, physical, and functional mock-up facilities within the simulation and development laboratories. Also, analytical and computational services are provided for all types of engineering design and research problems involving mathematical simulation. Basic disciplines employed are structural dynamics and aerodynamics in dealing with problems in aeroelasticity, loads, structural analysis, stability and performance analysis and optimization. The facility consists of the following components.

Digital - Three high-speed digital computers (DDP-19, DDP-24 and EAI 8400) are each capable of "Stand-Alone" processing or fully integrated hybrid operation. (a) The Computer Control Company (CCC) DDP-19 system features 32 bit, 32K core memory, 1 microsecond cycle time, a real-time interval timer, a 32 level priority interrupt system, an automatic data channel processor, a 600 lpm line printer, a 100 cpm card punch, an 800 cpm card reader, four 800 bpi magnetic tape units, a 500 cps paper tape reader, and a 110 cps paper tape punch. (b) The Computer Control Company (CCC) DDP-24 system provides a 24 bit, 12K core memory, 5 microsecond cycle time, an 8 level interrupt system, eight I/O channels, a real-time clock, a fully buffered channel, a 24 bit digital resolver, and a linkage system consisting of thirty-two 12 bit A to D channels, sixteen 12 bit D to A channels, and an analog command decoder. (c) The Electronics Associates, Inc. (EAI 8400) provides a 32 bit, 32K core memory, 1 microsecond cycle time, a real-time interval timer, a 32 level priority interrupt system, an automatic data channel processor, a 600 lpm line printer, a 100 cpm card punch, an 800 cpm card reader, four 800 bpi magnetic tape units, a 500 cps paper tape reader, and a 110 cps paper tape punch.

Converters - Analog-to-digital and digital-to-analog conversions are contained in the linkage systems of the DDP-19 and DDP-24 computers. Additional conversion is provided by an Electronic Associates, Inc. (EAI 8930) system which consists of thirty-two 14 bit A to D channels with S and H, thirty-two 14 bit A to D channels without S and H, and thirty-two 15 bit multi-digital-to-analog channels.

Analog - One or more fully expanded analog computers are available and are capable of being controlled by a digital computer (Analog Computer BB-1100 or EA1231-R). Analog equipment available includes: 13 consoles, 904 amplifiers, 540 inverters, 38 servo multipliers, 76 servo resolvers, 36 pot padding channels, 254 electronic multipliers, 208 manual diode function generators, 40 card programmed diode function generators, 22 six and eight channel recorders, 11 X-Y plotters; 2 analog magnetic tape recorder/reproducers, 1530 hand-set potentiometers, 200 servo-set potentiometers, and 4 electronic resolvers.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$4900	CONSTRUCTION YEAR: 1960-68 COST \$5,726,000 ESTIMATED REPLACEMENT VALUE \$6,500,000
CONTRACTOR: NAR Columbus Division	LOCATION: Columbus, Ohio
IMPROVEMENTS AND COSTS: (1969) Three-degree-of-freedom motion platform, Cost \$10,000; (1970) Servoed optical head, Cost \$80,000.	

PLANS FOR FACILITY IMPROVEMENTS: Improve camera transport performance, and improve visual displays.

VISUAL FLIGHT SIMULATOR: This device uses a closed-circuit television system to give the pilot a six-degree-of-freedom motion picture of the visible terrain. The pilot is thus subjected to a dynamically realistic simulation of the appropriate visual cues.

The pilot "flies" his mission while sitting in a full-scale cockpit which is installed in the projection room. He views a continuously changing picture projected onto a screen in front of the cockpit. His operation of the cockpit controls sends analog signals to the computer which, in turn, varies the panel instruments and also causes a television camera to follow the exact flight path and attitude of the vehicle. The camera views the model terrain and duplicates the pilot's view as seen from an aircraft flying the flight path he is controlling. This picture is transmitted to the projector and the screen for display to the pilot.

Applications include VTOL aircraft simulation, lunar landings, TV-guided missile studies, and carrier-approach investigations.

Terrain Model - The simulator uses three-dimensional terrain models of the desired scale mounted vertically on removable carts. The terrain models can be changed in 15 minutes for new problems. Content and scale of the model can be designed and fabricated to adapt the presentation to requirements of the specific study. Terrain models presently available include the following:

<u>Model</u>	<u>Scale</u>
Earth terrain	600:1
Earth terrain	3,000:1
Mid-Ohio terrain	1,200:1

Camera Transport Assembly - The camera transport assembly controls the attitude and position of the camera which provides a continuously moving picture of the terrain model. The camera has six degrees of freedom within the following limits:

<u>Linear Motion</u>		<u>Angular Motion</u>	
X	36 ft	Pitch	$\pm 70^\circ$ * $+45^\circ, -90^\circ$
Y	6 ft	Roll	$\pm 165^\circ$ * Continuous
Z	4 ft	Yaw	$\pm 330^\circ$ * Continuous

Control Console and Monitor - The control console includes a television monitor and the necessary controls for operating and monitoring the camera transport.

Cockpits - Fixed-base, full-scale cockpits are provided with longitudinal, lateral, directional, and throttle controls and a complete instrument panel. The instruments can be quickly changed, the panel readily adjusted vertically and the tilt-angle changed to suit different vehicle configurations. Conventional controls are available for fixed and rotary wing aircraft, and reaction controls for spacecraft. Adjustable stick feel and travel can be provided. A two-way communication circuit is installed in the cockpit to provide voice communication between the pilot and the computer operator.

A single-seat aircraft cockpit and a two-seat spacecraft cockpit are available.

A typical automobile driver's compartment mounted on a three-degree-of-freedom (pitch, roll and heave) motion platform is also available.

Projector - The projector accepts the picture seen by the television camera and displays it upon a screen which is visible to the pilot. The projector is capable of both front and rear screen projection and may be readily repositioned to suit the requirements of the particular simulation setup.

A servoed star field projector is available for space flights.

Presentation Screen - A 12 x 16 foot glass-beaded screen is placed approximately in the pilot's line-of-sight when he is seated in the cockpit. Normal field-of-view is about 50° . The picture transmitted by the camera to the projector is displayed on this presentation screen to provide the visual cue to the pilot.

*With 60° field-of-view servoed optical head.

TACTICAL WEAPONS SIMULATOR: This device, consisting of a large camera transport assembly and associated terrain models, provides longer duration flight simulation with a larger scale terrain model. Its operation is similar to the Visual Flight Simulator, and the device incorporates the same cockpits; however, the camera travels are greatly increased over those of the Visual Flight Simulator. It has been used for V/STOL studies, for landing studies requiring a longer approach, for midcourse missile guidance and control, and for spacecraft rendezvous and docking. A device which simulates atmospheric attenuation has been developed to provide for more realistic simulation of the target identification problem. The performance capabilities of the simulator are presented below.

Terrain Scale: 3,000:1 3-dimensional, colored

Terrain Size: 41'3" x 81'6" with a 40-ft diameter rotatable center section

Terrain Types: Includes flat, hilly and mountainous areas

Camera Limits: Linear Motion Angular Motion

X	70 ft	Roll	$\pm 165^\circ$ * $+45^\circ$, -90°
Y	32 ft	Pitch	$\pm 70^\circ$ * Continuous
Z	11 ft	Yaw	$\pm 330^\circ$ * Continuous

Display: TV monitor or large screen TV projection

TESTING CAPABILITIES: The Simulation Laboratory was originally designed to provide a facility for test, evaluation and development of air and space vehicular systems. The subsequent evolution of the facility provides capability of simulating internal and external environment and motion dynamics related virtually to any vehicular system. Simulation studies which may be conducted include physiological evaluations using a G-seat simulator, functional evaluations of control systems, structural dynamic evaluations, handling qualities, stability and performance evaluations, and evaluations of electronic systems including communication systems, antennas, marine systems and simulators.

FOUR-DEGREE-OF-FREEDOM DYNAMIC FLIGHT SIMULATOR: This device consists of a one-man cockpit which contains all normal flight controls, instrumentation, and switches, and a cathode ray tube display or a television monitor. The cockpit is provided with vertical, pitch, side, and roll freedoms which permit realistic rates and accelerations corresponding to typical flight conditions.

The cockpit motions are controlled through an analog computer which receives inputs from the pilot-operated flight control and stabilization systems.

- o Moving displays using TV, film or slides provided on an external screen 24 feet wide by 30 feet high can be provided to the pilot as well as conventional or (film slide) projected instrument panel displays, television monitor display, and a special cathode ray tube display.

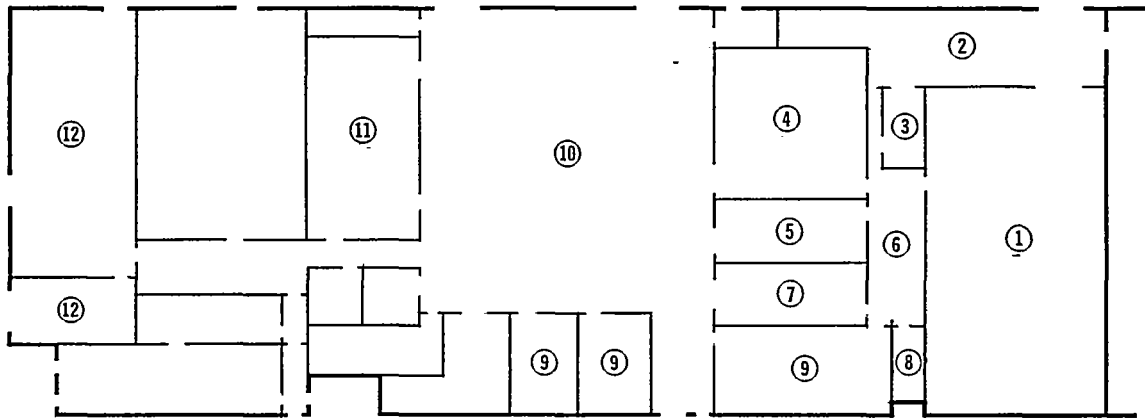
MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	None	± 10	± 2
*Velocity (ft/sec)		14	10
*Acceleration (ft/sec ²)		$\pm 161^{**}$	± 22.5
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 40	± 15	None
*Velocity (deg/sec)	2000	50	
*Acceleration (deg/sec ²)	1200	1000	

*Values indicated are maximum

** $\pm 5g$ (about 1-g earth)

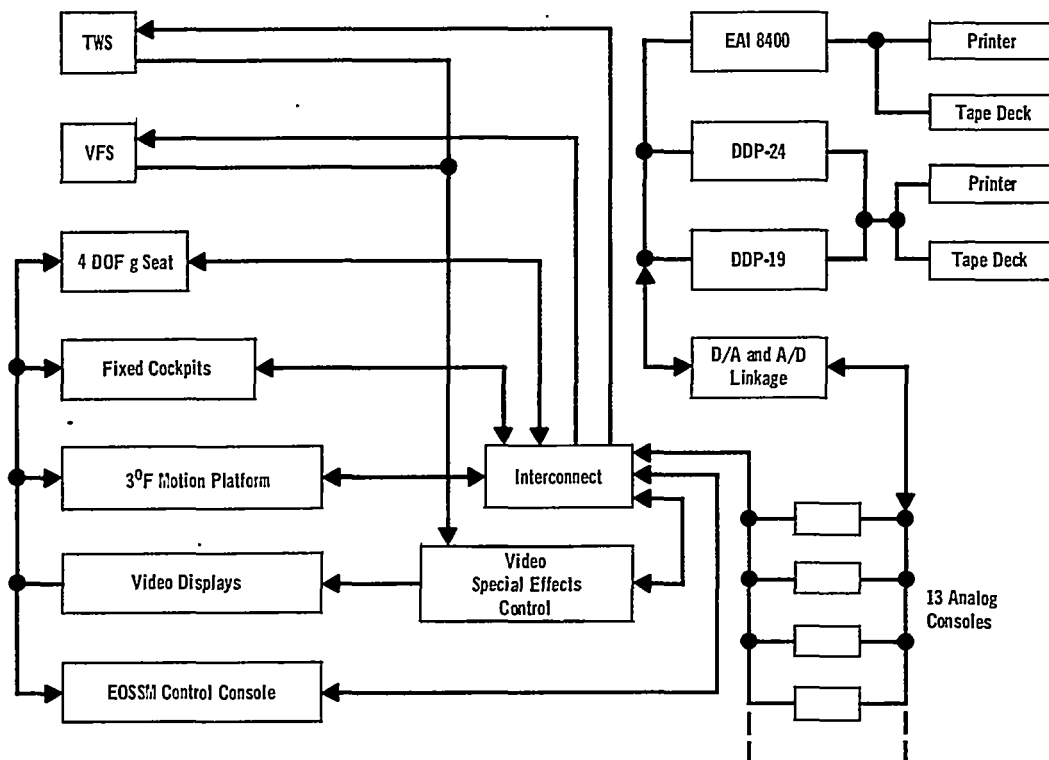
FACILITY LAYOUT



- | | | |
|-------------------------|------------------------------|-------------------------------|
| 1 TWS Area | 5 VFS Area | 9 Electronics Lab |
| 2 Shop Area | 6 TWS, VFS Control Room | 10 Aircraft Functional Mockup |
| 3 Special Effects Room | 7 Projection Room | 11 Office and Drafting Area |
| 4 Wide Angle Projection | 8 Variable Parameter TV Room | 12 4 DOF "g" Seat |

Computer Area (Not Shown) Located on Floor Directly Above the Laboratory Area.

OPERATIONAL DIAGRAM



NAR FLIGHT AND SYSTEMS SIMULATION LABORATORY

REPORTING INSTALLATION: North American Rockwell Corporation Los Angeles Division International Airport Los Angeles, California 90009	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Research and Engineering, Dept. 056
OTHER SOURCES OF INFORMATION: Flight and System Simulation, NAR Report NA-69-845	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight and Simulation Laboratory Group 094 - K. J. Dyda, Supervisor Phone: (213) 670-9151, ext 1881

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight and Systems Simulation Laboratory is housed under one roof covering 22,000 square feet of working area. This facility provides dynamic representation of manned aircraft in a realistic and accurate environment. The laboratory houses several simulation devices including a hybrid computer facility, a hover and transition (HOTRAN) simulator, a transport aircraft simulator (TAS), a vertical G-seat, a closed circuit television (CCTV) visual display system, and numerous support areas.

Crew stations can be equipped with a variety of sophisticated instrument and control characteristics specially developed for simulators capable of actual aircraft performance. These include: (a) a heads-up display (HUD) with a highly flexible symbol repertoire and complete computer control; (b) an extensive instrument array including a vertical scale indicator (VSI) (tapeline), an attitude-direction indicator (ADI), and scope displays; (c) control loading force servos with programmable linear and non-linear characteristics; (d) an aural cue generator. Also, terrain, horizon and target displays can be routed to any of the crew stations.

COMPUTER FACILITY: The computer facility provides real-time control of simulator dynamics. The computer system solves all variables and equations of the simulated aircraft mathematical model, generating electronic signals that control all flight instruments, visual system servos, and motion system actuators of the simulator. This completely integrated hybrid complex consists of a large digital computer, and eight analog computers. They are connected to each other through converters. The analog computer can be operated separately or under hybrid system control.

Digital - The digital computer is a general purpose Model XDS 9300 with a core memory of 24,576 words (expandable to 32,768 words), a disk storage of 524,288 characters (expandable to 2,097,152 characters), a word length of 24 bits (fixed point) or 48 bits (floating point), an input-output rate of over 570,000 words per second, 96 analog-to-digital and 96 digital-to-analog data converters, real-time features of 16 (interrupts) clock pulse generator, and a cycle time of 1.75 microseconds. Programming languages used are Real-time Fortran and DES-1 Symbolic.

Analog - The analog half of the hybrid system consists of eight general-purpose analog computers, Model EAI 231-R. Some specifications include +100-Volt reference, DC signal, 100 linear amplifiers per console, up to 56 multipliers per console, up to twenty 10-segment functions per console and a "Universal Non-linear Element" (UNE) highly versatile function generator or multiplier set.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1952 COST \$ Not Available
CONTRACTOR: NAR, Los Angeles Division	ESTIMATED REPLACEMENT VALUE \$ Available
IMPROVEMENTS AND COSTS: (1956) Central computer room; (1959) Maintenance and repair facility; (1961) Transport simulator; (1965) HOTRAN simulator; (1968) Digital computer installation (Hybrid Capability).	LOCATION: Los Angeles, California

PLANS FOR FACILITY IMPROVEMENTS: None

COMPUTER FACILITY (CONTINUED)

DATA HANDLING: A wide range of digital and analog data handling, recording, duplicating, and displaying equipment is available. A few examples are:

- o Line printer (1) 1,000 lines per minute
- o Card reader (1) 400 cards per minute
- o Card punch 300 cards per minute
- o Digital tape (3) 7 track, 800 bits per inch at 75 inches per second
- o Analog tape (2) 14 channels
- o Keyboard printer 10 characters per second
- o Oscillograph (11) 8 channels
- o Digital plotter 300 steps per second, X-Y or time base
- o Analog plotter 11 by 17 inches (3)
36 by 36 inches (1)
- o CRT display 64 channel symbol generator

Analog FM tape data is sampled and digitized at an effective rate of 38,000 samples per second. Use of sample-hold amplifiers prevents skewing. Inter-range instrumentation group (IRIG) time codes are used to select tape sections within 6 microseconds of the real-time position. Transcription accuracy is 98 percent overall.

SPECIAL SIMULATION HARDWARE: Displays have been designed and fabricated to provide flight information as an optical stimulus to the operator in the form of instrumentation and external visual presentations. A closed circuit television (CCTV) system may be used with any television projector or monitor and consists of a servo-driven terrain belt map, optical probe, television camera, and Schmidt projectors. Three projection systems are available and can be used either separately or simultaneously.

Terrain - The terrain model provides 1250:1 scaled hilly terrain and airport complex. A point source of light projects a large servo-driven transparency model onto a 200 by 90 degree screen. Projection scale factors from 375:1 to 60,000:1 are available.

Horizon - Another point source light projects a horizon and the upper atmosphere.

Target - A TV projector and gimbaled mirror cast the image of a maneuvering CRT - generated target model over the complete field of view.

G-SEAT: The G-seat was developed to investigate human factors in vibratory environments. The device consists of a single-place pilot station, controls, and an instrument panel, all mounted on a hydraulically actuated lever arm. Vertical acceleration capability is ± 50 feet/second².

HOTRAN SIMULATOR: The HOTRAN simulator provides three interchangeable cockpit configurations. They are a VTOL single-seat cockpit, a large VTOL transport pilot station and a fighter systems cockpit, any one of which may be mounted on a three-degree-of-freedom motion base. The cockpits may be equipped with any of the special instrument, control, computer, and display devices for accurately simulating aircraft performance characteristics.

COMBINED VISUAL DISPLAY MOTION PERFORMANCE:

Field of View	Azimuth $\pm 100^\circ$		Elevation $+30^\circ, -60^\circ$
Scene Attitude	Pitch $+29^\circ, -22^\circ$	Roll $\pm 25^\circ$	Yaw $\pm 540^\circ$
Flying Volume	Longitude * ± 70 in.	Latitude * ± 70 in.	Altitude * 0 to 9 in.
Target Bearing	Azimuth $\pm 90^\circ$		Elevation $+30^\circ, -60^\circ$
Target Range	300 to 30,000 ft		
Target Attitude (Aspect)	Continuous Rotation on Three Axes		

* Linear figures are multiplied times scale factor.

HOTRAN SIMULATOR (CONTINUED)

MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft) Velocity (ft/sec) Acceleration (ft/sec ²)	None	$\pm .5$ $\pm .83$ Unknown	None
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg) Velocity (deg/sec) Acceleration (deg/sec ²)	± 40 ± 20 Unknown	± 8 ± 20 Unknown	None

TESTING CAPABILITIES: HOTRAN was originally developed to study hover and transition phases of vertical takeoff and landing (VTOL) aircraft but its capability has been extended for the entire range of tactical aircraft simulation, including conventional fighters.

TRANSPORT AIRCRAFT SIMULATOR: The TAS system consists of a side-by-side dual seat cockpit which is mounted on a two-degree-of-freedom motion base. The cockpit features modular construction, reconfigurable instrument panels and a closed-circuit television visual (CCTV) system, all of which is programmed via the computer facility.

VISUAL DISPLAY MOTION:

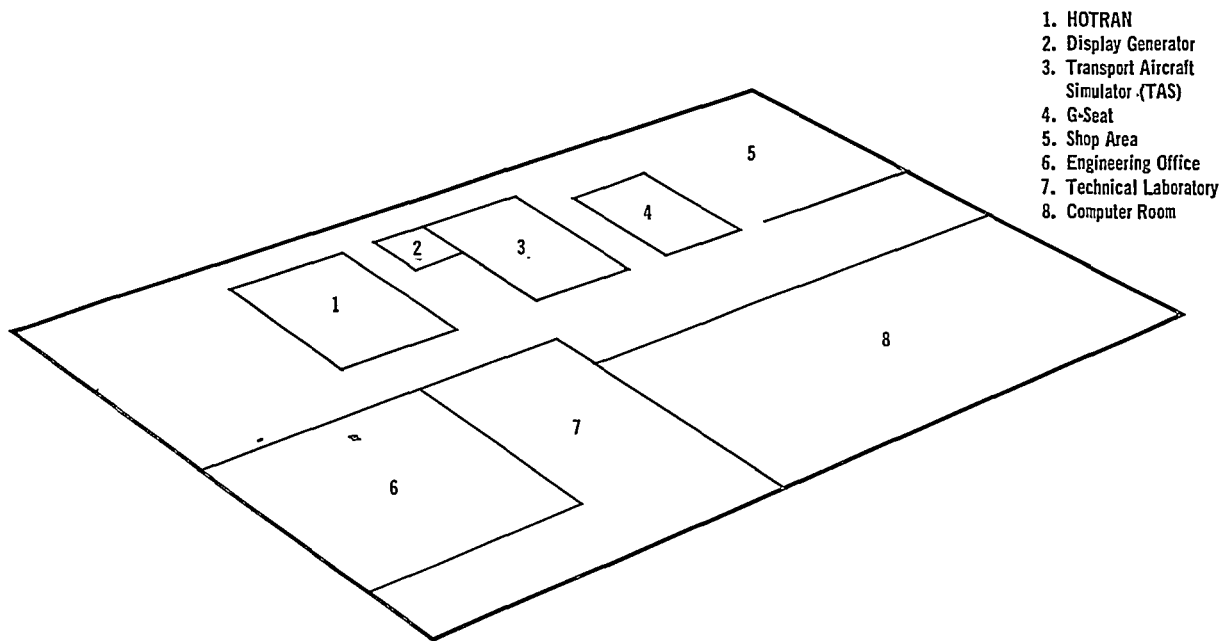
Linear Motion	Longitudinal	Vertical	Lateral
Range (miles) Velocity (ft/sec) Acceleration (ft/sec ²)	8.2 Unknown Unknown	0-.151 Unknown Unknown	± 2.9 Unknown Unknown
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg) Velocity (deg/sec) Acceleration (deg/sec ²)	± 90 ± 150 Unknown	± 25 ± 60 Unknown	± 540 ± 120 Unknown

MOTION SYSTEM PERFORMANCE:

Rotary Motion	Roll	Pitch	Yaw
Displacement (deg) Velocity (deg/sec) Acceleration (deg/sec ²)	± 15 ± 4 Unknown	+16, -8 ± 10 Unknown	None

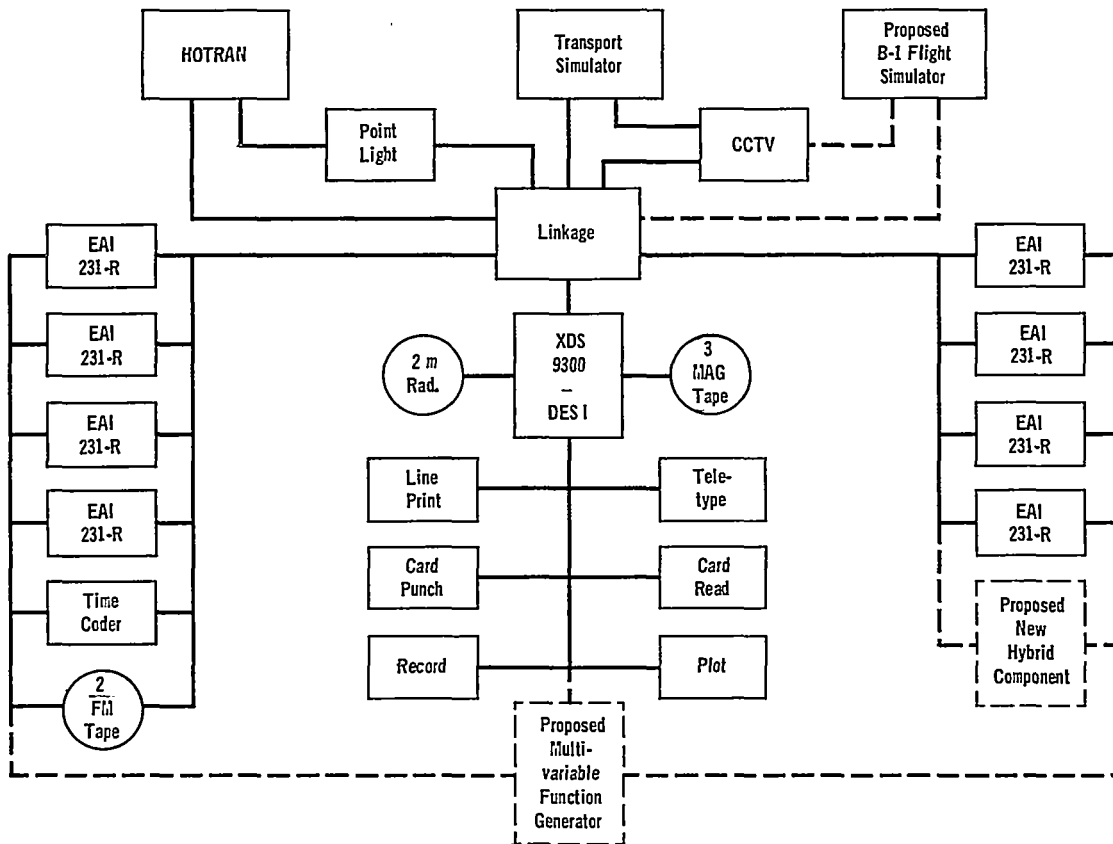
TESTING CAPABILITIES: The TAS was originally designed and developed to determine the validity of using motion base simulation to predict jet transport landing impact characteristics. This simulator has been used for handling qualities, control and display research and V/STOL transport research. Some of the aircraft for which simulations have been made are the XB-70, delta and swing-wing SST and the C-5A.

FACILITY LAYOUT



1. HOTRAN
2. Display Generator
3. Transport Aircraft Simulator (TAS)
4. G-Seat
5. Shop Area
6. Engineering Office
7. Technical Laboratory
8. Computer Room

OPERATIONAL DIAGRAM



NAR FLIGHT SIMULATION LABORATORY

REPORTING INSTALLATION: North American Rockwell Corporation Space Division 12214 Lakewood Boulevard Downey, California 90241	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Flight Technology, Dept. 190
OTHER SOURCES OF INFORMATION: Facilities and Industrial Engineering, Dept. 085, D. T. Young, Mail Code AD62	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Simulation, Dept. 190 J. M. Robertson, Mail Code DA25 Phone: (213) 922-4245

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Flight Simulation Laboratory provides functional simulation support to the various projects of the Space Division. The equipment includes both analog and digital computers, fixed base crew station mock-ups with active controls and displays, visual display generation and presentation equipment, a dynamic motion simulator, and special-purpose simulation equipment.

Vehicle characteristics and major subsystems can be simulated either unmanned or man-in-the-loop. For man-in-the-loop simulations, the crew stations are interconnected to either analog or hybrid computer systems for real-time problem solution. Computer signal outputs can be used to drive the visual displays for operator visual cueing. The space mission flight phases which can be simulated with visual cueing are boost aborts, orbital maneuvers, navigational problems, rendezvous, docking, entries and landings on either earth or moon.

The facility is comprised of four main simulation entities: computers and their peripheral equipment, crew stations, external visual displays and special-purpose equipment.

COMPUTER COMPLEX:

Digital - One digital computer is an XDS 9300 with 32K memory, 8 I/O channels, 64 priority interrupts, 4 tape units, a line printer, a card reader, and a card punch. A second XDS 9300 is leased and is interconnected to the above machine.

Converters - Analog-digital and digital-analog conversions are provided by an ADAGE 406.2 and a PBC-3005.

Analog - The 1688 amplifier analog computer system includes 12 EAI 231-R's, 3 EAI TR-48's, 1 Beckman 300, and 2 EAI 350 digital operations systems.

CREW STATIONS: The facility includes two Apollo-type command modules, one with window and sextant-telescope visual displays, and one general purpose crew station which may be configured with various controls and displays for special studies.

VISUAL DISPLAY SYSTEMS:

Earth-Moon System - This system consists of a 6 foot diameter, high resolution-rendered earth globe with variable inclination capability and rotatable about the polar axis and an orbital axis; a 4 foot diameter moon globe; and a transport system carrying a TV camera/near object probe system. The system is computer controlled and can provide visual cues for orbital and trajectory problems.

Starfield Generators - A 24 inch diameter, gimbaled starfield globe with 1353 positioned stars, together with a TV system, provides celestial scenes for spacecraft orientation and navigational studies. A second celestial sphere provides navigational cues for the general-purpose crew station.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): \$8600	CONSTRUCTION YEAR: 1964-69 COST \$ 7,000,000* ESTIMATED REPLACEMENT VALUE \$11,000,000
CONTRACTOR: NAR, Corporation	LOCATION: Downey, California
IMPROVEMENTS AND COSTS: No major additions since 1969.	
*Estimate	

PLANS FOR FACILITY IMPROVEMENTS: Improved and expanded visual display system during 1971; Integrate small special purpose computer into complex during 1971.

VISUAL DISPLAY SYSTEMS (CONTINUED)

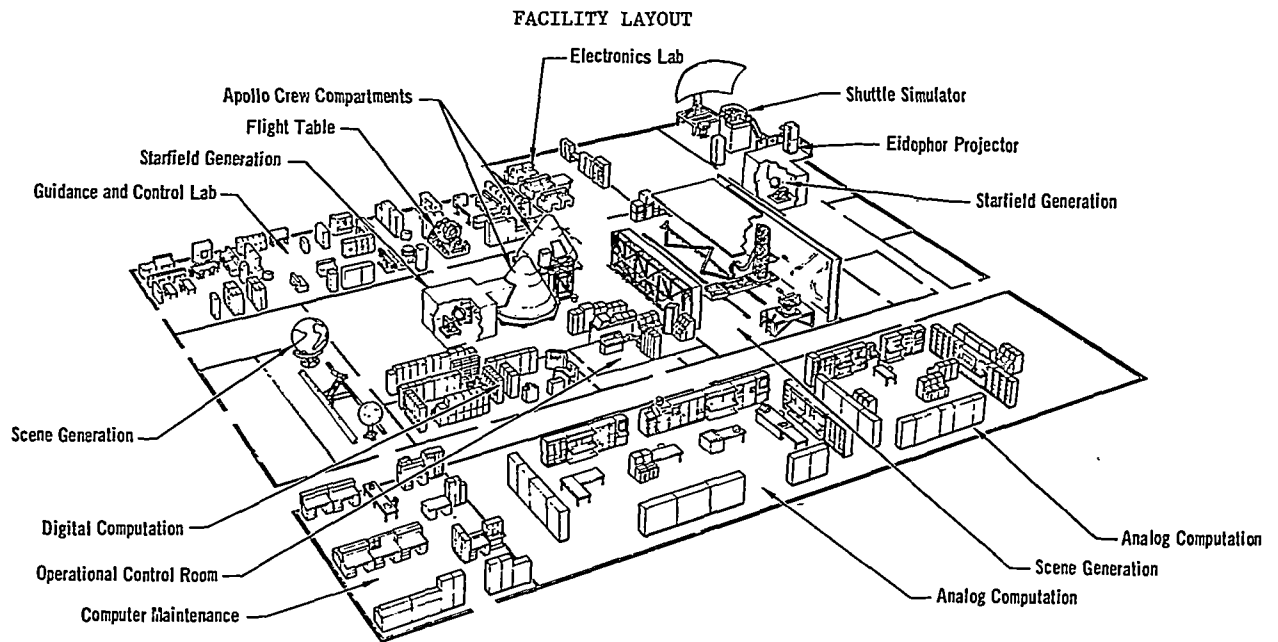
General-Purpose Visual System - This system is composed of one three-dimensional moonscape panel 12' x 12', 400:1 scale; one three-dimensional moonscape panel 10' x 20', 1500:1 scale; a two-dimensional landing field representation 15' x 56', 720:1 scale; one two-dimensional United States map 20' x 45', 400,000:1 scale; a three-degrees-of-freedom transport with ranges of 45', 17' and 10' on each of the axes; a near object probe; a three-degrees-of-freedom model gimbal system; an Eidophor projector with 25' radius projection screen; and accompanying TV cameras and monitors. The system is used in simulations of atmospheric flight, landing, space rendezvous, lunar excursion, etc.

TV Systems - A 1203-line vidicon system is installed to provide orbital and celestial visual cues to the spacecraft crew station. The General-Purpose Visual System utilizes a 945-line image-orthicon system. The TV systems are interconnected such that correct visual cues, wherever initiated, may be presented to the two flight stations and to control station monitors. Matting generators incorporated in the systems provide the capability of presenting combined planet, starfield, rendezvous-vehicle scenes as required.

SPECIAL SIMULATION EQUIPMENT:

Dynamic Motion Simulator - This three-degrees-of-freedom simulator having a 200-lb, 25" diameter x 25" volume load capacity has the capability of imparting dynamic motion to guidance system inertial sensors or an inertial platform. Possible accelerations are $1080^\circ/\text{sec}^2$ in roll and $3960^\circ/\text{sec}^2$ in pitch and yaw; and displacements can be up to 1080° roll and 240° pitch and yaw.

Other - Other major special purpose equipment includes electronic simulations of spacecraft inertial measurement unit, jet select logic, reaction control and fuel accounting systems; a master interconnect system for the analog computer complex; and a memory interface connect system to interface the XDS 9300 digital computer to simulated systems and to control the visual displays.



OPERATIONAL ARRANGEMENT

The 13 analog computer sections and the two HYDAC's are interfaced through a master interconnect system to the digital computers and to a simulation master interconnect rack which, in turn, interfaces with the three flight stations and the general purpose system. The digital computers are interconnected to the two spacecraft flight stations, the visual displays and the special purpose simulation equipment through a memory interface connect. This system facilitates multiple study operations and minimizes changeover time.

TELEDYNE RYAN FLIGHT SIMULATION LABORATORY

REPORTING INSTALLATION: Teledyne Ryan Aeronautical Company 2701 Harbor Drive San Diego, California 92112	STATUS OF FACILITY: Active COGNIZANT ORGANIZATIONAL COMPONENT: Dynamics and Simulation, Dept 340
OTHER SOURCES OF INFORMATION:	LOCAL OFFICE TO CONTACT FOR INFORMATION: Flight Simulation, Department 340, R. L. Vance Phone: (714) 291-7311, ext 558

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The Facility consists of a hybrid computer, and supporting analog and peripheral equipment.

The primary tasks are the development and use of 6-degree-of-freedom simulations for engineering evaluation, pilot training, and hardware studies.

DIGITAL COMPUTER: The EAI 8400 has the following complement:

- o Floating point hardware
- o 24,000 words memory
- o Card reader
- o 4-mt drives
- o Paper tape I/O
- o Control desk with typewriter

HYBRID INTERFACE: Consists of:

- o Control lines
- o 16-16 bit DACS
- o 16 channels mux ADC

ANALOG COMPLEMENT: Consists of:

- o One 231-R GPAC
- o One 8800 GPAC
- o Five 31-R GPAC's

PERIPHERAL EQUIPMENT: Consists of:

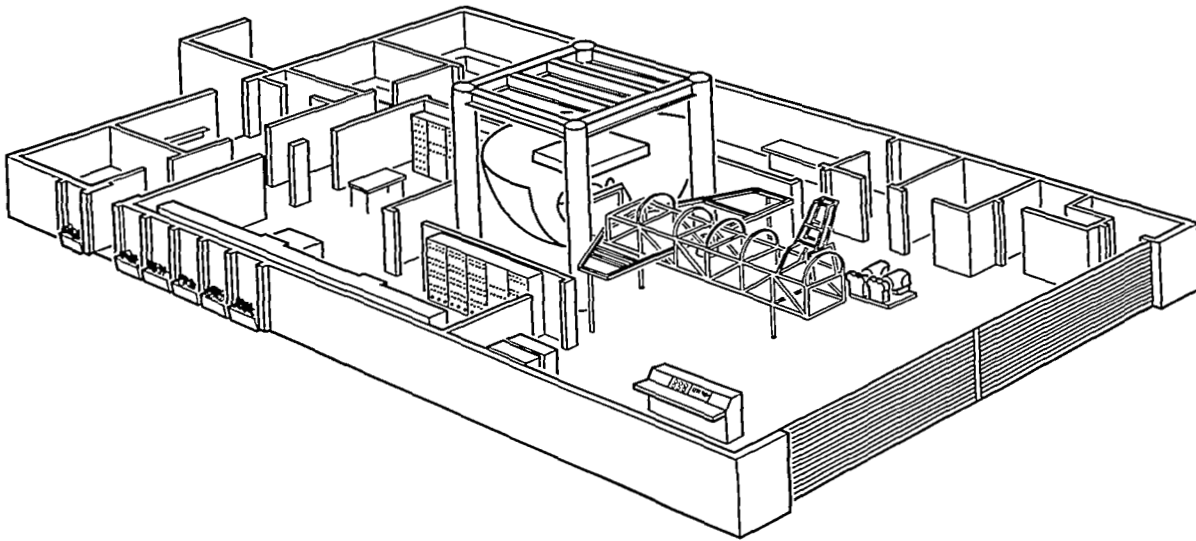
- o Three 8 channel oscillographs
- o One 30" x 30" X-Y plotter
- o One EAI 3500 digital plotter
- o Misc. function gen.

FACILITY COST HISTORY

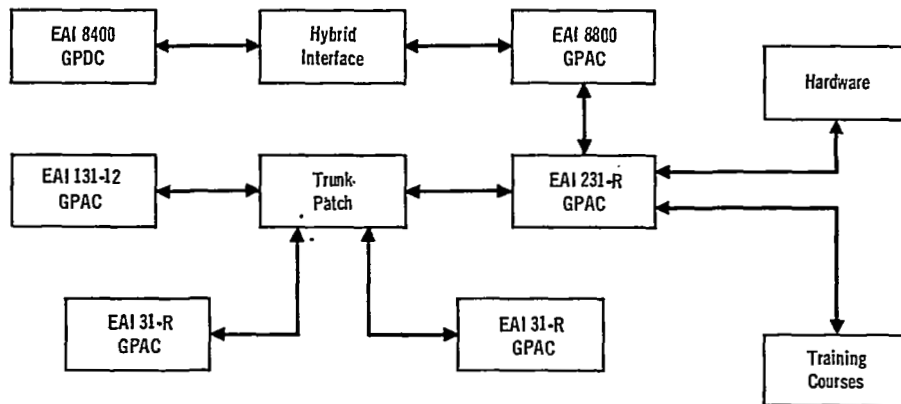
AVERAGE ESTIMATED OPERATING COSTS (TYPICAL 8-HOUR SHIFT): \$400	CONSTRUCTION YEAR: 1962 COST \$ 125,000.00 ESTIMATED REPLACEMENT VALUE \$ 180,000.00
CONTRACTOR: Trepte Construction Company IMPROVEMENTS AND COSTS: Not Available	LOCATION: San Diego, California

PLANS FOR FACILITY IMPROVEMENTS: Expansion to training facility, possibly including training computer.

FACILITY LAYOUT



OPERATIONAL DIAGRAM



UARL V/STOL MOVING BASE SIMULATOR

REPORTING INSTALLATION: United Aircraft Corporation Research Laboratories Silver Lane East Hartford, Connecticut 06108	STATUS OF FACILITY: COGNIZANT ORGANIZATIONAL COMPONENT: Sikorsky Aircraft North Main Street Stratford, Connecticut 06497
OTHER SOURCES OF INFORMATION: Sikorsky Aircraft Division B. Bollert (203) 378-6361	LOCAL OFFICE TO CONTACT FOR INFORMATION: Simulation Laboratory R. Belluardo Phone: (203) 565-5385

DESCRIPTION AND TESTING CAPABILITIES

FACILITY DESCRIPTION: The V/STOL simulator is operated by the UARL Simulation Laboratory and consists of a two-seat fully enclosed cockpit with functional dual flight controls, instruments, visual displays, and a six-degree-of-freedom motion system. Central to the simulator complex is the control station, which has a duplication of all cockpit displays as well as instruments for monitoring the system status.

Control forces as a function of any flight parameter can be applied to all of the controls and spring centering of the control stick is available independent of the force system. Two 21-inch TV monitors mounted in the windshield present a contact analog real-world display to simulate VFR flight. Advanced IFR displays can be generated by combining the contact analog with digital information which is presented on 9-inch TV monitors, mounted in the instrument panel.

The six-degree motion system consists of six hydraulic actuators arranged so that their mounting points form vertices of an octohedron. Extension and contraction of the actuators relative to each other determine the motion of the cockpit. The stroke of each actuator is controlled by a Digital Equipment Corporation PDP-8 computer. With this arrangement pure uncoupled linear and angular motions can be obtained in all six degrees of freedom.

Central to the Simulation Laboratory operation is a Digital Equipment Corporation PDP-6 digital computer, which operates simultaneously as a general-purpose, time-shared facility for the Research Laboratories and as a real-time hybrid or digital simulation facility. Four simulation consoles, used for non-time-dependent interactive simulation, provide access to and control over user programs on the PDP-6 via a panel of pushbuttons and lights and a standard teletype. In conjunction with three Beckman Analog Computers, the PDP-6 also may function as a real-time hybrid facility. A full complement of interchangeable Brush strip-chart recorders and Omnigraphic X-Y plotters provide a high degree of flexibility to the system. In addition, a general-purpose graphical display (Digital Equipment type 340) is directly accessible as an output device for PDP-6 programs. A character generator and vector generator are a part of the scope hardware.

COMPUTER SYSTEM:

Digital - The Digital Equipment Corporation PDP-6 computer is equipped with 64,000 36-bit words, seventeen teletype stations, six DEC tape units, a paper tape reader and 1.5 million words of auxiliary drum storage, used for program swapping and permanent storage. Digital Equipment Corporation PDP-1 and PDP-9 processors "share" memory with the PDP-6, providing a high-speed interface to graphic output devices and simulation consoles.

Analog - Two Beckman 1100 series and one Beckman 2133 series analog computers provide a full complement of amplifiers and non-linear equipment for the laboratory. This equipment may be interfaced to the PDP-6 via 40 ADAGE D/A channels and 40 Raytheon A/D channels.

FACILITY COST HISTORY

AVERAGE ESTIMATED OPERATING COST (TYPICAL 8-HOUR SHIFT): Not Available	CONSTRUCTION YEAR: 1961-69 COST \$1,500,000 ESTIMATED REPLACEMENT VALUE \$2,500,000
CONTRACTOR: Sikorsky Airc. & Franklin Inst. Res. Labs.	LOCATION: Stratford Conn. & Philadelphia, Penn.
IMPROVEMENTS AND COSTS: (1969) Six-degree-of-freedom motion system, Cost \$525,000.	

PLANS FOR FACILITY IMPROVEMENTS: Improved visual display system.

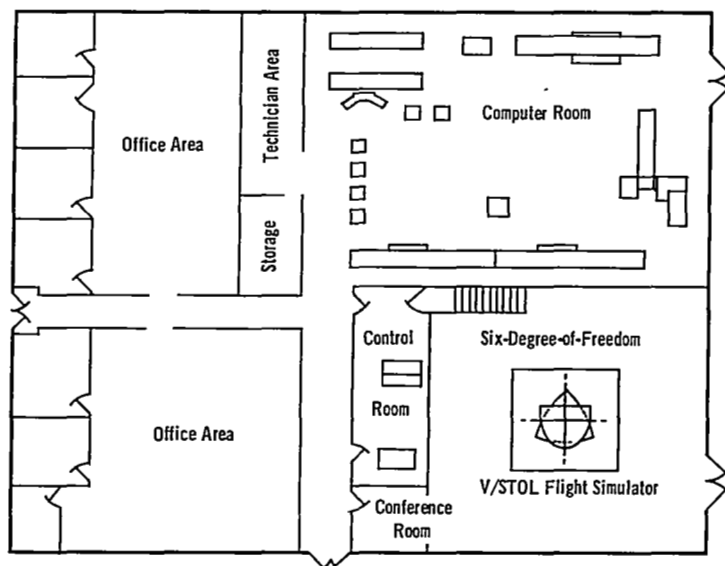
COMPUTER SYSTEM (CONTINUED)

MOTION SYSTEM PERFORMANCE:

Linear Motion	Longitudinal	Vertical	Lateral
Displacement (ft)	± 5	± 2.5	± 5
Velocity (ft/sec)	± 3	± 3	± 3
Acceleration (ft/sec ²)	± 31.7	± 31.7	± 31.7
Rotary Motion	Roll	Pitch	Yaw
Displacement (deg)	± 30	± 45	± 45
Velocity (deg/sec)	± 35	± 35	± 38
Acceleration (deg/sec ²)	± 120	± 120	± 143

TESTING CAPABILITIES: This moving base simulator provides a tool for realistically appraising the performance of pilot-vehicle dynamics for proposed V/STOL aircraft systems and subsystems. It is used to evaluate handling qualities, control system configurations, and flight information displays, and to develop new tactics for mission tasks. It can also be used to develop new methods of presenting handling qualities criteria and quantitative measures of pilot's task performance, and to establish design criteria goals.

FACILITY LAYOUT



OPERATIONAL DIAGRAM

